

# **Environment, Trade and Growth Nexus in Asian Countries: An Empirical Analysis**

Thesis submitted during 2021 to the University of Hyderabad in partial fulfilment for  
the award of

**Doctor of Philosophy**

In

Economics

by

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## **CERTIFICATE**

This is to certify that the thesis entitled **“Environment, Trade and Growth Nexus in Asian Countries: An Empirical Analysis”** submitted by **Mohd Arshad Ansari** bearing registration number 16SEPH17 in partial fulfilment of the requirements for the award of Doctor of Philosophy in the School of Economics is a bonafide work carried out by him under my supervision and guidance.

The thesis is free from plagiarism and has not been submitted previously in part or full to this or any other university or institution for award of any degree or diploma.

Further, the student has the following publications before submission of the thesis.

A) Published in

- i) OPEC Energy Review, Vol. 43, Issue: 02, 2020 ISSN: 1753-0237 (Chapter two of the Thesis).
- ii) Ecological Indicators Journal in Vol. 115, Issue: March 2020, ISSN: 1470-160X (Chapter three of the Thesis).
- iii) Ecological Indicators Journal in Vol. 121, Issue: February 2021, ISSN: 1470-160X (Chapter four of the Thesis).

B) Presented at

- i) International Conference on Globalization and Development sponsored by UGC-SAP (DRS-II) on 23<sup>rd</sup> & 25<sup>th</sup> February, 2018, Visva-Bharati, West Bengal, India.
- ii) International Seminar on Rural Development in Asia Pacific Region on March 24<sup>th</sup> & 28<sup>th</sup>, 2020, National Institute of Rural Development, Guwahati, India.
- iii) International conference on Sustainable, Finance, Economics, and Accounting in Pre and Post Pandemic Era at Indian Institute of Management (IIM) Jammu, Jammu and Kashmir, India on July 30<sup>th</sup> & 31<sup>st</sup>, 2021.

Further, the student was exempted from doing course work (recommended by doctoral committee) on the basis of the following courses pass during his M.Phil. Program and the M.Phil. degree was awarded.

| S. No. | Course Code | Course Title                    | Credits | Results |
|--------|-------------|---------------------------------|---------|---------|
| 01     | EC701       | Advanced Economic Theory        | 4       | Pass    |
| 02     | EC702       | Social Accounting and Data Base | 4       | Pass    |
| 03     | EC703       | Research Methodology            | 4       | Pass    |
| 04     | EC571       | Study area                      | 4       | Pass    |

(Prof. Naseer Ahmed Khan)  
Signature of the Supervisor

(Prof. R.V. Ramanamurthy)  
Dean, School of Economics

## DECLARATION

I, **Mohd Arshad Ansari**, hereby declare that this thesis entitled, “**Environment, Trade and Growth Nexus in Asian Countries: An Empirical Analysis**”, submitted by me under the guidance and supervision of **Prof. Naseer Ahmed Khan** is a bonafide research work. I also declare that it has not been submitted previously in part or in full to this University or any other University or Institution for the award of any degree or diploma.

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Signature of the Student

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## **Acknowledgement**

First and foremost, I am grateful to my thesis advisor Prof. Naseer Ahmed Khan, for her constructive comments, valuable suggestions, timely guidance, and insightful discussions throughout my Ph.D. program. I equally thank him for his kindness and encouragement at each and every stage in the preparation of this thesis. I am extremely indebted to him as I have gained a great learning experience.

I extend my thanks to Doctoral Committee members Dr. Prajna Paramita Mishra and Dr G Vijay for their valuable comments and suggestions throughout my research work. I also extend my gratitude to Prof. B. Kamaiah for his valuable suggestions. I would also like to express my sincere thanks to my father Mr. Badruddin Ansari for continuous inspiration. I am also thankful to all the faculty members of the School of Economics, University of Hyderabad for their guidance and support throughout my coursework. I sincerely thank the Dean, Prof. R.V. Ramanamurthy for being accessible and offering encouragement in completing this work.

I would also like to acknowledge the support of fellowship section and library staff of University of Hyderabad for their academic resource support. I am very grateful to the support of University Grants Commission, Government of India for providing financial support for pursuing my Ph.D. Further I express my sincere regards to ICSSR, New Delhi and CMIE for providing valuable resource for conducting this research. Moreover I express my gratitude to World Bank research Foundation, Global Reporting Initiative to facilitate data collection. I would acknowledge the provision from developer of Eviews and Stata to allow use of its software. I sincerely thanks Mr. Salman Haider for his continuous encouragement.

Further, I take this opportunity of thank my seniors and friends, Dr. Adil Ganaie, Dr. Sajad, Dr. Zulkarnain, Dr. Tariq Masood, Dr Javed, Dr. Kashif Khan and other colleagues. Finally, I will never find enough words to fully express my gratitude to my parents and family members for their love and support throughout my academic journey.

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## **Abbreviations**

|                 |                                             |
|-----------------|---------------------------------------------|
| ADB             | Asian Development Bank                      |
| ADF             | Augmented Dickey Fuller                     |
| AEIR            | Asian Economic Integration Report           |
| ARDL            | Autoregressive Distributed Lag Model        |
| ASEAN           | Association of Southeast Asian Nations      |
| BRICS           | Brazil, Russia, India, China, South Africa  |
| CADF            | Cross Sectionally Augmented Dickey-Fuller   |
| CIPS            | Cross Sectionally Augmented Im-Pesaran-Shin |
| CO <sub>2</sub> | Carbon dioxide                              |
| DFE             | Dynamic Fixed Effects                       |
| DOLS            | Dynamic Ordinary Least Square               |
| DV              | Dummy Variable                              |
| EC              | Energy Consumption                          |
| ECT             | Error Correction Term                       |
| EF              | Ecological Footprint                        |
| EKC             | Environmental Kuznets Curve                 |
| EU              | European Union                              |
| FDI             | Foreign Direct Investment                   |
| FMOLS           | Fully Modified Ordinary Least Square        |
| EX              | Export                                      |
| G               | Globalization                               |
| GCC             | Gulf Cooperation Council                    |
| GDP             | Gross Domestic Product                      |
| GFN             | Global Footprint Network                    |
| GHG             | Green-House Gas                             |
| GHA             | Global Hectare                              |
| GMM             | Generalised Method of Moment                |
| IEA             | International Energy Agency                 |
| IM              | Import                                      |
| IPS             | Im-Pesaran- Shin                            |
| JEF             | Japan Ecological Footprint                  |
| K               | Composition Effect                          |
| MENA            | Middle East And North Africa                |
| MG              | Mean Group                                  |
| LM              | Lagrange Multiplier                         |

|                 |                                                       |
|-----------------|-------------------------------------------------------|
| MMT             | Million Metric Tonnes                                 |
| MTOE            | Million Tonne of Oil Equivalent                       |
| NAFTA           | North American Free Trade Agreement                   |
| OECD            | Organisation for Economic Cooperation and Development |
| OLS             | Ordinary Least Square                                 |
| PHH             | Pollution Haven Hypothesis                            |
| PMG             | Pooled Mean Group                                     |
| PP              | Phillips-Peron                                        |
| PPP             | Public-Private Partnership                            |
| PRC             | People's Republic of China                            |
| PWT             | Penn World Table                                      |
| SDG             | Sustainable Development Goal                          |
| SEI             | Swiss Economic Institution                            |
| SO <sub>2</sub> | Sulfur Dioxide                                        |
| TO              | Trade Openness                                        |
| UAE             | United Arab Emirates                                  |
| UN              | United Nations                                        |
| UNCTAD          | United Nations Conference on Trade and Development    |
| URB             | Urbanization                                          |
| US\$            | U.S. Dollar                                           |
| WDI             | World Development Indicators                          |
| WER             | World Energy Resources                                |
| WIR             | World Investment Report                               |
| WTO             | World Trade Organisation                              |
| WWF             | World Wildlife Fund                                   |
| Y               | Economic Growth                                       |
| Y <sup>2</sup>  | Square of Economic Growth                             |
| Z               | Scale Effect                                          |
| Z <sup>2</sup>  | Technique Effect                                      |

## Chapter 1

### Introduction

#### 1.1: The Asian economies: An overview

Asia is the world's largest continent, comprises more than 4.4 billion people (60 per cent of the world Population)<sup>1</sup> and thus offers concentrations of cheap labour. Japan in addition to be a source country of foreign direct investment (FDI), is also the fastest growing economic region as well as the largest continental economy by both public-private partnership and gross domestic product (GDP) nominal in the world<sup>2</sup>. In the recent decade China and India are the first and third largest economies in Asia, respectively. Moreover, Asia is the site of some of the world's longest modern economic booms, starting from Japan, then in South Korea, Singapore, Hong Kong, Malaysia and Indonesia, among others<sup>3</sup>. In case of the West Asian countries namely Saudi Arabia, Qatar, United Arab Emirates, Bahrain, Iran, Kuwait and Oman, prosperity has been largely due to these countries' vast reserves of oil and other forms of non-renewable energy, in particular, gas. China, India, Japan, South Korea, Indonesia, Turkey, Iran, Saudi Arabia and other countries of Asia are largest in terms of purchasing power parity GDP (Barros et al., 2013). The good prospects for the Asian economies have ensured that FDI has continued to flow into these countries, despite financial crisis that rocked the Asian Pacific countries in 1997 (World Investment Report (WIR), 2016), and despite the many military conflicts and tensions that have plagued certain Asian regions and continue to destabilise others. However, Middle East depend more on engineering to overcome climate difficulties for economic growth and the production of commodities, whereas East Asian and Southeast Asian countries generally rely on manufacturing and trade<sup>4</sup>.

According to the statistics reported in the UNCTAD database, during the period from 1970 to 2011, the more advanced developing countries welcomed the major share in FDI, more than 90 per cent of total FDI inflow, while the least developed Asian countries attracted the least amount of FDI, accounting for less than 1 per cent on average. But during the period from 2014

---

<sup>1</sup> Population of Asia in 2014" World population statistics

<sup>2</sup> <http://www.imf.org/external/datamapper/NGDPD@WEO/OEMDC/ADVEC/WEOWORLD>

<sup>3</sup> Due to their rapid development and industrialization in the 1980s, Hong Kong, Singapore, South Korea and Taiwan became known as the Asian Dragons. In the 1990s, Thailand, Malaysia, Indonesia and the Philippines also experienced strong growth, earning them the name of Asian Tigers.

<sup>4</sup> <http://www.e-ir.info/2014/10/16/the-asian-tigers-from-independence-to-industrialisation>

to 2015 the global FDI inflows increased by 38 per cent and global FDI inflows to Asia by sub regions are 59.9, 3.0, 9.2, and 23.8 per cent for which East Asia accounting for highest FDI inflow followed by Central Asia, South Asia and Southeast Asia respectively according to the Asian Economic Integration Report (AEIR) (2016). Furthermore, with the implementation of an open-door policy and the start of a program of structural reforms in Hong Kong and China attracted large FDI volumes, to underscore its importance as a hub for financial investment, with Singapore and India following. This also explains the large FDI flows between China, People's Republic of China (PRC) and Hong Kong, (AEIR, 2016)

## 1.2: Economic outlook

Stating the Asian financial crisis, Table 1.1 shows the regional economic growth. Despite an unfavourable external environment, developing Asia's economy grew at 5.9 per cent in 2017 from 5.8 per cent in 2016. A rebound in global trade, PRC are likely to hold better economic growth by showing strong and better GDP which grew at 6.7 per cent in 2017. On the contrary the economic growth of PRC during the 2016 was eased to 6.7 per cent as compare to 7.0 per cent in 2015. This was due to the restructure of the economy toward consumption from export led growth. Steady progress of reform in India boosted its growth led by an unanticipated rise in external demand and expansionary fiscal policy.

**Table 1.1: Economic growth (region wise in per cent)**

|                              |      |      |      |      | Forecast <sup>5</sup> |      |
|------------------------------|------|------|------|------|-----------------------|------|
|                              | 2013 | 2014 | 2015 | 2016 | 2017                  | 2018 |
| Developing Asia <sup>6</sup> | 6.5  | 6.4  | 6    | 5.8  | 5.9                   | 5.8  |
| Central Asia                 | 6.6  | 5.2  | 3.1  | 2.2  | 3.3                   | 3.9  |
| East Asia                    | 6.8  | 6.6  | 6.1  | 6    | 6                     | 5.8  |
| People Republic of China     | 7.8  | 7.3  | 6.9  | 6.7  | 6.7                   | 6.4  |
| South Asia                   | 6.2  | 6.9  | 7.3  | 6.7  | 6.7                   | 7    |
| India                        | 6.6  | 7.5  | 8    | 7.1  | 7                     | 7.4  |
| Southeast Asia               | 5    | 4.6  | 4.6  | 4.6  | 5                     | 5.1  |

Sources: ADB calculations using data from ADB (2017); (accessed September 2017). World Development Indicators.

As compared to 2016, more than 70 per cent of the region's economies have seen faster growth with higher rates in all sub-regions except for South and East Asia, where regions growth rate this year is stable (Asian Development Bank (ADB), 2017). Strong growth together with rising

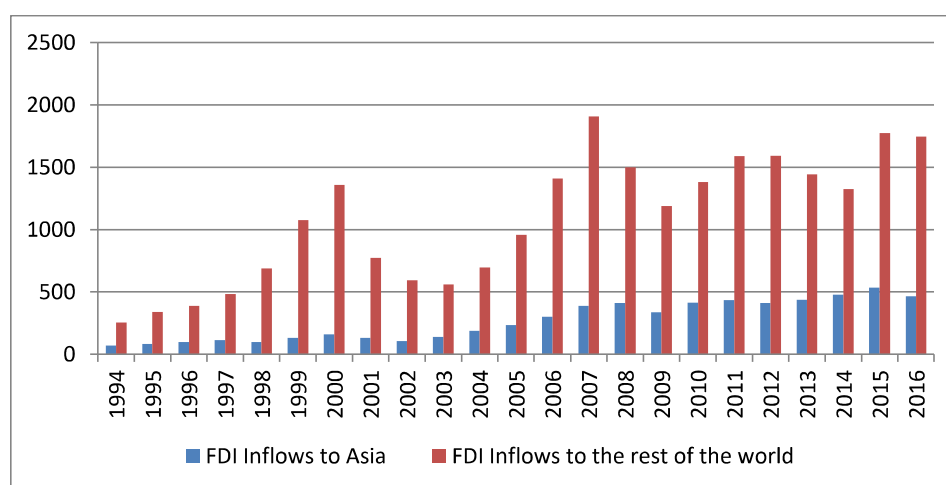
<sup>5</sup> Forecasts based on ADB (2017).

<sup>6</sup> Comprises 45 Asian developing bank developing countries

infrastructure investment and higher export prices for commodities is expected to continue in Southeast. Excluding PRC, in Asia's eight largest developing economies saw FDI increasing, where real manufacturing exports rebound particularly in electronics (ADB, 2017).

### 1.3: Trends and patterns of FDI in Asia

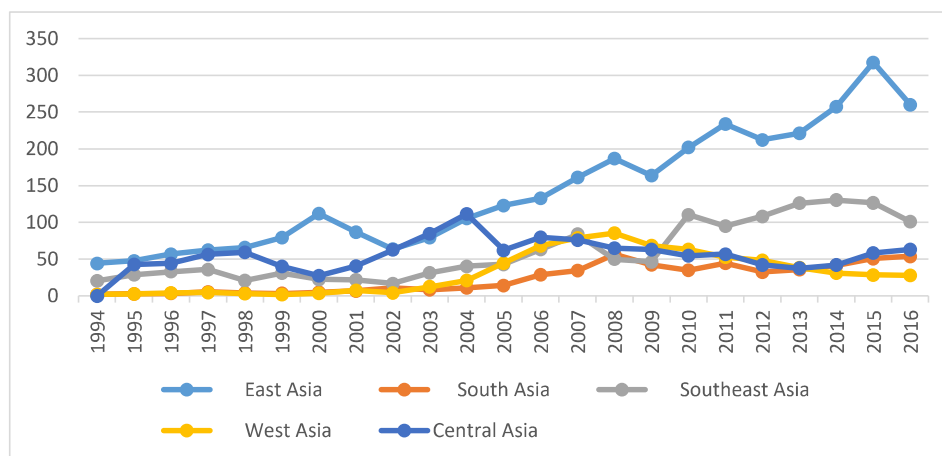
For the last two decades the advantages of increased investment and trade, benefited numerous Asian countries with rising income and strong growth output, which helped in achieving regional integration and inclusive economic growth. Over the last few decades, the main features of economic globalization are multinational's central role in the capital flows to Asian emerging countries. There are few facts observed as follows. First, the share of Association of Southeast Asian countries (ASEAN) countries has dropped and china enjoyed the highest share in the region. Second, direct investment to Asia has remained stable. Third, commercial bank lending to Asia show large swing before and after the Asian financial crisis. Lastly, security investment still play an important role as a source of capital to Asia. Therefore, the cross border investment- production network has created an opportunities even in the region for low income countries to stimulate export led growth mechanism contributing directly to total factor productivity via knowledge and technological spill overs as well as enhancing economic growth through human capital and physical accumulation thereby accelerating economic development for developing and capital starved countries (ADB, 2017).



**Figure 1.1: Total Inward FDI (\$ billion/trillion)**

Source: WDI (2017)

After having fallen since 2012, globally the share of Asia's inward FDI surged to nearly \$ 466.3 billion in 2016. Global FDI inflow in 2016 declined to \$ 1.75 trillion, down slightly from \$ 1.77 trillion in 2015 (Figure 1.1). This was due to steep decline in cross border investment especially in services. Inward FDI to North America, transition economies and other advanced economies attracted more FDI while FDI to Europe and developing Asia fell. In Asia: India, Singapore, China, Hong Kong and the PRC remained the main recipient with \$44.5, \$48.2, \$61.6, \$108 and \$133.7 billion respectively (ADB, 2017). From the figure it is clear that since 1994 the FDI inflows to Asia kept on increasing whereas FDI to rest of the world also showed the upward trend.



**Figure 1.2: FDI inflows to Sub regions (\$ billion)**

Source: WDI (2017)

Figure 1.2 shows the global inward FDI to Asian countries by sub region. By sub-region, East Asia was one of the top destinations of FDI in 2015, accounting for almost 60 per cent of all Asia bound global FDI mainly coming from three countries PRC, China and Hong Kong. On the contrary the major sub-regions of Asia's inward FDI felt slightly, affecting East and Southeast Asia significantly. The data shows inward FDI declined for Asian countries both in relative and absolute terms as global investments favoured most advance countries. Therefore the inward FDI to Asia declined to \$492 from \$525.4 billion during the period 2015-2016. Furthermore the regions share of total FDI is dipped to 28 per cent from 30 per cent in the year 2016, also for Southeast Asia and East Asia by 20 per cent and 14 per cent respectively (see Figure 1.2). The slowdown in East Asia was drop in inward FDI to China and Hong Kong by \$66 billion was the reason behind the decline in FDI share. There was a marginal increase in inward FDI share in South Asia by 3 per cent to \$50.4 billion, further showing except Bhutan and Afghanistan all the economies were above the 2015 level where the top three sources of inward FDI were Singapore, Japan and Mauritius accounting for 90 per cent of total FDI in

India. It grew 56 per cent, 32 per cent, and 4 per cent to Pakistan, Sri Lanka, and Bangladesh, respectively.

#### 1.4: A brief overview of the Pollution haven & Environmental Kuznets curve hypothesis

Pollution haven hypothesis (PHH) and an inverted U-shaped linkage between economic growth and environmental quality commonly known as Environmental Kuznets curve (EKC) hypothesis have gained much attention due to its important role in determining the quality of environment in the past. Initially, the environmental quality deteriorates with the economic progress and rises at the later due to rise in growth levels and industries tend to employ clean technologies. However, when applied universally, evidences have shown that inverted U-shaped relationship is not true. Due to less stringent environmental regulation, developed economies invest in developing countries for setting up of polluting industries. As a consequence, the advance nations may depend on developing nations to supply them with dirty products. The progress in the FDI or trade among the countries may lead to enhance in emission, as the nation ultimately leading to the existence of PHH. So, PHH holds true, then EKC shows a shift of environmental degradation from advance countries to developing nations rather than mitigating the overall greenhouse gas emissions level. Such pattern of international investment are created by PHH whereas EKC hypothesis explains the reason of decrease in the emissions level in developed countries.

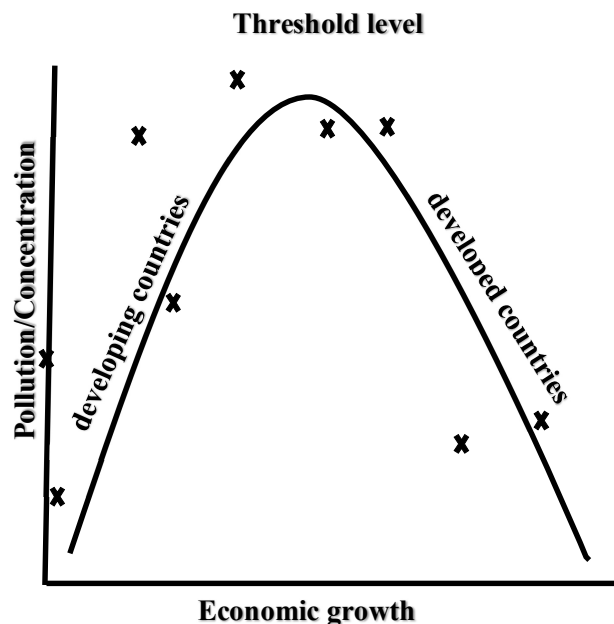
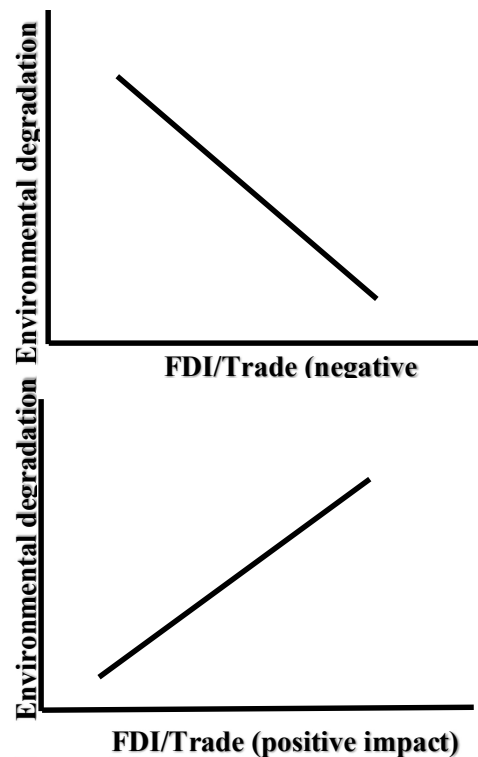


Figure 1.3 Graphical depiction of the EKC hypothesis

Source: Author's calculation (2020)

As can be observed from Figure 1.3, an inverted U-shaped curve exhibit which validate EKC. This is because, after a threshold point, environmental degradation begins to reduce as economic growth continues to rise. The possible reason for this occurrence is that more advance economies adopt environmental friendly and cleaner technology. As a results, after a threshold point, countries become more aware about the environment for which they use environmental friendly products to lower the emissions levels in their country. Second, the dirty production may be taking place more in the developing economies. Instead, more advance economies specialize in the cleaner production. Because dirty production shift to less developed from developed economies, these developing countries are considered as pollution havens. If this is the case, much of the shift may gave to do with increased FDI, comparative advantage, trade openness, increased regulations, and globalization.

Figure 1.4 shows the linkage between FDI/trade and environmental degradation. Increased in FDI decreases environmental pollution which has negative impact on the economies showing nonexistence of PHH while in another case FDI has positive impact with environmental degradation which validates PHH. In other words, the implication is that foreign investors use worse management practices and shift dirty goods in the host countries resulting in increasing the level of environmental pollution in the host countries.



**Figure 1.4: Pollution Haven hypothesis**  
Source: Author's calculation (2020)

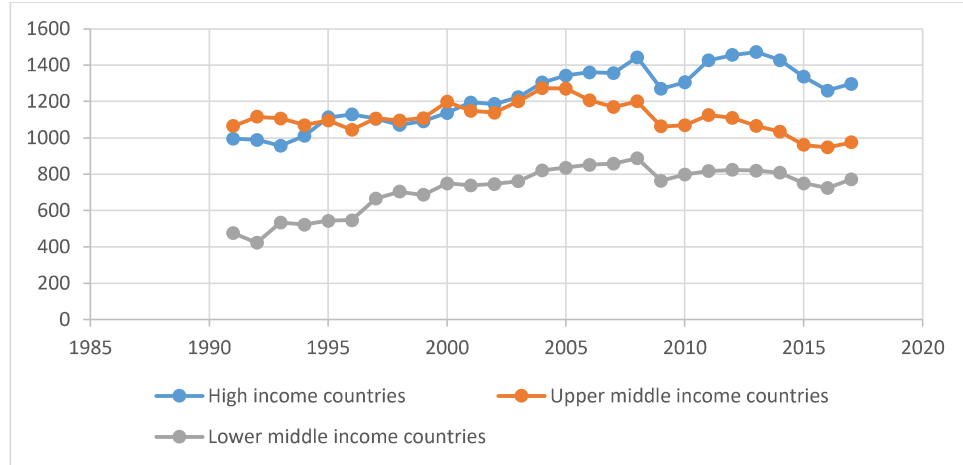


### **1.5: An overview of trade and environment**

Today, developed nations are in favour of opening economies as well as for more trade openness, as export and import has positive impact on country's growth. This changing pattern of trade has started the debate that more openness in trade may cause environmental improvement globally. Following standard Stolper-Smuelson model of trade, all firms would shift to less-pollution-intensive good techniques and price paid for using environment would be bid up. Yet, following the Heckscher-Ohlin theorem, a country would be relatively environment abundant with having low factor price ratio. There would be a specialization in the pollution intensive products because of the trade openness and there would be no change in the overall use of environment in the Heckscher-Ohlin model of trade (Halicioglu, 2009; Khalil and Inam, 2006). The openness in trade has statistically significant effect on environmental quality was first carried out by Grossman and Krueger (1991). The promoters of trade openness claims that trade encourage economic activity and liable to deterioration of environmental quality if the methods of production remains unchanged. The proponents of trade openness suppose that if environmental quality treated as normal product due to relax environment regulation then firms in less developed economies will move from high to low standard of production techniques and this action may affect the income distribution at global level. On the other hand, oppositions of trade openness claim that the country discourage the use of outdated and old methods of production and presumes trade improves the quality of environment and economy as a whole. The authorities treat quality of environment as normal good and demand clean environment, as the level of traded income rises. Since developed nations enforce harsh environmental regulations, trade openness increases pollution intensive goods in developing countries thereby having adverse impact on the quality of environment (Ahmed et al., 2019).

Although theoretical association between quality of environmental and trade openness is not clear, but as it structure of comparative advantage changes, firms in developed countries raised the issues over dirty production of goods to less developing countries. Firms in developing nations have to face less stringent environment as compared to advance nations and are more concerned that liberalization in international trade will encourage the production of dirty industries, thus causing serious concern over environmental problems to the country (Laspidou et al., 2020). The present globe is now split into trade openness and trade blocks likely to affect not only the quality of environment enjoyed by all the states of the country but also socio economic well-being of the countries in trade blocks; such that environmental problem on one hand, trade relationship on the other is widely accepted and well established (Baylis, 2005).

The trend of trade openness by Asian income group countries shows an increasing trend in each income group (Figure 1.5). The figure shows that high income countries of Asia are more openness to trade than upper middle and lower middle income countries.



**Figure 1.5: Trend of trade intensity of Asian income countries (As per cent of GDP)**  
Source: WDI (2020)

## 1.6: Problem statement

There is a voluminous literature on PHH and EKC analysis in the case of developed countries. Attention has also been paid to developing one, but there is no single study that examine these hypothesis in sub regional Asian countries together. By sub-region, East Asia continues to be the primary destination, accounting for 60 per cent of all Asia bound global FDI driven primarily by the PRC and Hong Kong. South Asia and Southeast Asia also posted a slight increase, with 9 per cent and 24 per cent, respectively, of the total inflows to the region (AEIR, 2016). According to WIR (2016), developing Asia is now the largest recipient and accounts for almost one-third of total FDI inflows. It is expected that the PHH might take place in the sub-regions of Asian countries since FDI inflow is at an increasing rate. Therefore, it is important to examine the validity of PHH in sub region of Asian countries for better policy implications

A great number of studies examine the issues of EKC hypothesis in the case developed and developing economies. Their research employed CO<sub>2</sub> emission to examine the validity of EKC model. Extensive studies have been conducted to examine the driving factors behind environmental pollution. Given the fact that CO<sub>2</sub> emission is the primary cause of climate change, majority of studies used it as an indicator of environmental pollution. However it is criticized to use it as sole proxy of environmental pollution. Since it ignore other major

pollutant (such as deforestation, water pollution, soil erosion, grazing) which too contributes to environmental deterioration. So outcome may be misleading when using CO<sub>2</sub> emissions solely as proxy for environmental pollution. Therefore, one must use inclusive environmental indicator to obtain better understanding between economic growth and environmental damage to the country. For this purpose the chapter employed ecological footprint (EF) indicator to compute cumulative human pressure on the environment. Therefore, it is essential to analyse the validity of the EKC hypothesis in these sub regions to fill the research gap and to make predictable policy implication using broader concept of environmental indicator.

Hence an extensive research is required for key determinants and environmental performance analysis from an economic point of view. However, some studies have analysed trade openness through scale, technique and composition effect analysis. The underlying aggregate trade openness may differ from decomposition of trade intensity which needs to be estimated with appropriate statistical tools. Tracking trade openness performance over time is quite pertinent in a dynamic world. Therefore, there is a need to undertake a comprehensive study to evaluate the trade openness performance of the Asian income group countries and benchmark its performance. The study provides policy implication for economic development and environmental quality from an economic point of view. Overall, this study comprehensively analyses the potential to enhance economic development (at sub region of Asia and income based Asian countries) and reveal the underlying root-cause of different determinants and environmental performance outcome. It shed insights to improve FDI, economic growth, trade openness and environmental problems.

This will assist policymakers and corporate managers of Asian countries in analysing different measures to adopt. This study has chosen the Asian countries due to the highest FDI inflow to the region and its widening bio capacity resources. The gap between the natural resource demand and the environment's ability to replenish those resources (bio capacity deficit) in Asian countries is widening. Further, the trade between the Asian economies and rest of world is also increasing where literature shows that increase trade among the countries might affect the environment too. These region group has been recognised as highly polluting environmental resources and mismanagement of resources in the country. Moreover, monitoring the energy efficiency performance can provide valuable inputs for evaluating of energy efficiency consumption through alternate energy use such as renewable energy consumption. It helps to reduce fossil-fuel consumption also as a way to achieve sustainable development goals.

### **1.7: Objectives and Hypotheses of the Study**

The main aim of the thesis is to analyse the environmental quality level across the Asian countries. Further, the thesis explored the potential drivers of environmental degradation like economic growth and other key determinants.

The specific objectives of the study are as follows:

1. To analyse the impact of foreign direct investment on environmental quality performance of Asian countries at sub regional level.
2. To analyse the linkage between economic growth and environmental degradation of Asian countries across different sub regions.
3. To analyse the impact of trade openness on the environmental quality based on the income group of Asian economies

Based on the above objectives, the following hypothesis is formulated:

- (i) There is a positive impact of foreign direct investment on environmental degradation (considerable existence of Pollution haven hypothesis).
- (ii) There is a positive association between economic growth and environmental degradation (non-existence of environmental Kuznets curve hypothesis).
- (iii) There is a positive relationship between trade openness and environmental degradation.

### **1.8: Data and Methodology**

The thesis follows the international to source data from the Annual data for Asian countries. Annual data for per capita GDP, FDI, energy consumption, trade openness, urbanization, carbon dioxide (CO<sub>2</sub>) emissions has been extracted from the World Bank's World Development Indicators database, while EF data has been taken from Global Footprint Network. Globalization data has been taken from the Swiss Economic Institution. It provides data from the annual balance which is mainly measured in three parameters such as socially, political, and economically. Further Capital-Labour ratio data have been taken from the Penn World Table version 9.0.

The thesis mainly considers long run estimates like Pooled mean group to estimate long run coefficients at sub region Asian panels. It is basically an augmentation of Autoregressive

Distributed lag model, and take care of heterogeneity which restrict long run coefficients. It allow short run coefficients to vary across countries together with error variances and intercepts. There is also an adjustment mechanism toward long-run equilibrium from any short run deviation known as error correction term (ECT). Hence, the possible endogeneity can also be removed by applying suitable form of lags of different variables in the ECT

Further, fully modified ordinary least square (FMOLS), dynamic ordinary least square (DOLS) analysis has been conducted to examine long run coefficients. This technique uses a nonparametric approach to address the issue of serial correlation and endogeneity. These estimators have advantage in eliminating autocorrelation problem in the residual terms and endogeneity issues in the explanatory variables (Bhattacharya et al., 2016). In addition, by using parametric approach DOLS methods gets rid of the problem of its lags and leads of the regressors while the FMOLS technique eliminates the problem of serial correlation and endogeneity.

### **1.9: Scope of the Study**

The thesis considers sub panels of Asian countries to analyse PHH and EKC, and role of trade openness on the quality of environment has been examined based on income group of Asian countries. It departed from the earlier study in the sense that it takes cross sectional dependence and heterogeneity into account which is mostly ignored by previous studies. Moreover, this thesis used EF indicator as a proxy for environmental quality to examine EKC hypothesis and to assess the role of trade openness on environmental quality which is important for policymaking at management and regional level. The best practice approach has been adopted in this study and advocates an advance panel approach to take into account cross sectional dependence issue. It applied PMG, FMOLS and DOLS to estimate to consider determinates at the regional and income level. Scope of this study is that FDI increased higher rate of employment and economic growth in the country. With the advantage that comes with FDI is the creation of job opportunities. Increased FDI boosts the overall manufacturing as well as service sector. It is amongst the most important reason that helps with the growth of nation. It is expected that the PHH might take place in the sub-regions of Asian countries since FDI inflow is at an increasing rate. The study provides an understanding of FDI in Asian countries and it impact on environmental degradation that has potential to enhance environmental quality and economic growth. If the PHH is valid, policymakers have to find ways to mitigate that;

otherwise reducing FDI inflow may retard the economic growth of a country. Therefore, it is essential to examine the validity of the PHH in the Asian sub-region countries.

Further, the study has adopted EF indicator as a proxy for environmental quality to measure the pollution level in the context of EKC hypothesis. Asia's ecological assets continues to rise at a faster pace than Earth's bio capacity and relatively higher than all other regions, this is mainly due to sharp increase in higher economic growth and decline in the productive ecological resources along with inadequate resource management. Asian countries are potential contributor to environment degradation globally, hence this study will adds to the debate on the EKC. Therefore, it is essential to analyse the validity of the EKC hypothesis in these sub regions to fill the research gap and to make predictable policy implication. Moreover, the trade in Asian countries is increasing which might have adverse impact on the environmental quality. Therefore, it is pioneering effort in examining the association between the EF and trade effect by adding scale, technique, and composition effects in EF function.

#### **1.10: Limitations of the study**

This study has considered a broader view to examine the PHH, EKC and trade-environment nexus in Asian countries by considering cross sectional dependence and heterogeneity, so the results cannot be generalized. The unavailability of data is one of the significant problem that arouse during the study. To determine the PHH, the nexus between FDI and environmental quality has examined. While to investigate EKC hypothesis EF indicator is taken. Moreover, the study focuses on the scale, technique and composition effect, and the comparative advantage effect is ignored. Moreover, the collective impact of aggregate energy consumption is examined, and the individual role of renewable and non-renewable energy consumption is not taken into account. These limitations supervise researchers to investigate further studies by taking Asian sub regions geographically or ASEAN countries. By employing disaggregate role of renewable and non-renewable energy use, the same study can also be conducted. In order to analyse validity of EKC hypothesis same issue can be conducted taking material footprint as a proxy for environmental quality which a production based indicator introduced by Wiedmann et al. (2015). Further, PHH can be re-examined either using ecological or carbon footprint. The factors like human capital, financial development, population density also cause the CO<sub>2</sub> emissions and EF, so these variables should also be examined in future research.

### **1.11: Chapter Scheme**

The thesis has been organised into five chapters. First chapter provides a broad introductory remark on Asian economies, Economic outlook, trends and patterns of foreign direct investment in Asia, a brief overview of PHH and EKC and an overview of trade and environment are presented. It also includes research problems, scope, objectives and limitations of the study. In chapter two, foreign direct investment and environmental quality analysis across different regions is discussed. Chapter three explores economic growth and environmental quality analysis across sub panels of Asian countries. Chapter four examines the impact of trade effect on the environmental quality indicator. The last chapter provides a summary of the thesis, conclusion and policy implications of the study.

## Chapter 2

### Foreign Direct Investment and Environmental Quality: A Regional Prospective

#### 2.1: Introduction

Foreign direct investment (FDI) worldwide has grown markedly since the 1970s, reaching \$1.76 trillion in 2015. According to World Investment Report (WIR) (2016), developing Asia is now the largest recipient and accounts for almost one-third of total FDI inflows. The economic diversification had become a main economic and political priority in the Asian economies. This goal of economic diversification is initiated when the Asian countries started to encourage foreign investors and private sectors to increase their role in the Asian economies to accomplish more economic liberalisation. This new economic policy opened a wider range of activities to FDI, (WIR, 2016) which helped in inclusive economic growth and integration by enhancing total factor productivity through technological and knowledge spillovers through physical and human capital accumulation. This contributes directly to economic growth, thereby facilitating economic development for capital starved and technologically backwards developing countries. FDI inflows to developing Asia are expected to increase by 15 per cent in 2017, as an improved economic outlook in major Asian economies is likely to boost investor confidence in the region (WIR, 2016) since they are moving towards more economic liberalisation. Presently, global FDI has become especially challenging; many investors are forced to hold their investments in the Middle East and the Asia Pacific. Moreover, by allowing economies to link to global and regional value chains, FDI potentially facilitates regional integration an export-oriented development strategy that many in Asia have followed successfully. FDI is an important source of capital which can enhance technological transfer to the host countries and stimulate economic growth and development. To invest abroad, Japan is one of the countries that exert great efforts among the countries in the Asian region, mostly Southeast Asia region.

In general, FDI has the following three important effects on the host country economy: (i) filling the gap between targeted investment and domestic savings (Bosworth et al., 1999) (ii) boosting said country's development efforts (Alfaro, 2003) (iii) offering itself as a source of external capital (Bustos, 2007). Furthermore, FDI can also aid innovative learning may provide direct capital financing; generate positive externalities such as a mixture of technical skills which consequently stimulate economic growth, through technology transfer, productivity gains spillover effects and the introduction of new processes (Lee, 2013). Copeland and Taylor



(1994), Cole (2004) finds that developing countries tend to undermine environmental concerns through relaxed or non-enforced regulation, which is termed as pollution haven hypothesis (PHH).

Rapid industrialisation has led to increasing environmental concerns, such that the links between foreign investment and environment pollution have been intensely debated. Some studies (Atici, 2012) found that FDI inflows can reduce pollution by transferring environment friendly technologies from developed to less or weak developed countries, while some other studies (e.g. Cole and Elliott, 2005; Cole et al., 2006; Wang et al., 2013) found that FDI inflows have a positive effect on pollution. This positive relationship between FDI and carbon emissions known as PHH which defines that the pollution intensive firms or industries are more likely to move from developed or advance countries to developing countries because the environmental regulation in these countries is weak or less stringent.

## **2.2: Literature review**

The branch of research on the relationship between FDI and economic growth in environmental sustainability remains debatable worldwide due to contradictory empirical results. There have been many studies conducted to examine the CO<sub>2</sub> determinants. Energy consumption and economic growth are two important determinants of CO<sub>2</sub> and research found that energy consumption and output have a significant positive effect on CO<sub>2</sub> emissions. However, some studies observed that the relationship between FDI and CO<sub>2</sub> emissions is negative. On the other hand, some studies observed that the relationship between FDI and CO<sub>2</sub> emissions is positive, thus supporting the PHH.

In this context, Hitam and Borhan (2012) and Wang et al. (2013) found the positive relationship between FDI and CO<sub>2</sub> emissions in China and Malaysia. Using the generalised method of moment estimator, He (2006) also arrived at the same conclusion that FDI has a positive effect on pollution via its impact on output growth in the Chinese provinces. Further exploring the PHH and the environmental impact of FDI in 29 Chinese provinces' Cole et al. (2006) suggest that due to the low stringent environmental policies, less developed countries are always the best choice of investment. In one of the study, Atici (2012) analyse the relationship between CO<sub>2</sub> emissions, exports, growth and the Japanese FDI to Association of Southeast Asian countries (ASEAN) countries and found that FDI has no impact on the CO<sub>2</sub> emissions in ASEAN countries whereas exports and growth have a significant positive effect on CO<sub>2</sub>

emissions. To examine the impact of FDI and output on the environmental quality in 112 major cities in China, Cole et al. (2011) employed the panel data approach and found that FDI and economic growth have a statistically significant and positive effect on water and air pollutions in these major cities, supporting the PHH in the Chinese economy.

The PHH received considerable attention in developing countries (Kearsley and Riddel 2010). Using data from the countries forming the Gulf Cooperation Council, Al-Mulali and Tang (2013) investigated the validity of the PHH, by applying panel cointegration and causality approaches. Their result suggested that CO<sub>2</sub> is increased by economic growth and energy consumption but lowered by FDI. Besides other, some related studies were conducted on developed and the Central and East European countries. For instance, Waldkirch and Gopinath (2008), Jorgenson (2009), and Lee (2009) for Malaysia, less developed countries and Mexico, also found that FDI has a positive effect on pollution, thus supporting the existence of PHH, respectively. By contrast, Tamazian and Rao (2010) showed that FDI decreases CO<sub>2</sub> emissions in the case of 24 transition economies. Lindert and Williamson (2007) work for the less developed economy showed that the foreign investor export pollution-free technology to the host country, resulting in pollution free environment.

Shao et al. (2019) investigated that PHH does not exist in case of BRICS countries. Nadeem et al. (2020) used autoregressive distributed lag model (ARDL) and employed four different indicators of environmental degradation to explore the existence of PHH in Pakistan over the period from 1971 to 2014. Their empirical findings indicate that FDI inflow and Sulfur dioxide (SO<sub>2</sub>) emissions show negative long run relationship while FDI inflow and Greenhouse gas (GHG), CO<sub>2</sub> and CO<sub>2</sub> from solid fuels show positive long run relationship. Hence they did not find any evidence in support of PHH. For Asian economies, Hanif et al. (2019) examined the short run and long run impact of economic growth, FDI, energy consumption on carbon emissions and concluded that FDI is a significant source of environmental pollution in 15 developing Asian countries. Khan and Ozturk (2020) investigated the causal linkages among CO<sub>2</sub> emissions and FDI in case of Asia. The findings indicate that the panel cointegration confirms the presence of long run association and found bidirectional granger causal between CO<sub>2</sub> emissions and FDI inflow. By employing panel data technique Huynh and Hoang (2019) revealed that FDI inflows affect air pollution in 19 Asian economies. Destek and Okumus (2019) analysed the linkages between energy use, country's growth, FDI and environmental pollution in newly industrialized countries. Their results showed that PHH exist for their country.

It appears from the literature review which clearly shows FDI is the main activity which creates the pollution. However, it is hard to say the PHH is certain. Moreover, none of the previous studies has investigated and compared the hypothesis in the five panels of Asian countries namely West, Central, East, South and Southeast Asia. Therefore, it is essential to empirically examine the validity of the PHH in the Asian sub-region countries.

FDI outflows from Japan and Taiwan to ASEAN countries like Malaysia, Indonesia, Thailand, Cambodia, from the European Union (EU) to the Eastern Europe and others. By sub-region, East Asia continues to be the primary destination, accounting for 60 per cent of all Asia bound global FDI and driven primarily by the PRC and Hong Kong. South Asia and Southeast Asia also posted a slight increase, with 9 per cent and 24 per cent, respectively, of the total inflows to the region (AEIR, 2016). Japan is the dominant source of FDI in Asia, while the People's Republic of China (PRC) is the most popular host. East Asian economies such as the PRC, Japan and the Republic of Korea were among the top 10 Asian sources of global FDI and in Southeast Asia, Singapore and Malaysia (AEIR, 2016). It is expected that the PHH might take place in the sub-regions of Asian countries since FDI inflow is at an increasing rate. The main goal of this chapter is to examine whether FDI inflows have any significant impact on pollution in the five sub-region of Asian panel countries such as West Asia, Central Asia, East Asia, South Asia and Southeast Asian countries. These countries are highly polluted because the level of CO<sub>2</sub> emissions increased by more than 200 per cent (International Energy Agency (IEA), 2016). If the PHH is valid, policymakers have to find ways to mitigate that; otherwise reducing FDI inflow may retard the economic growth of a country. Therefore, it is essential to examine the validity of the PHH in the Asian sub-region countries. To examine the validity of the PHH in the sub-region of Asian countries, panel unit root tests developed by Im et al. (2003) and Xuehua and Nini (2011) is used to investigate the order of integration using the Im-Pesaran-Shin (IPS) and ADF-Fisher. Secondly, to investigate the presence of a long-run equilibrium relationship between CO<sub>2</sub> emissions and its determinants, the panel cointegration proposed by Pedroni (1999), is implemented.

The main interest of this chapter is to analyse the validity of the PHH. Therefore, special attention will be given to the relationship between FDI and CO<sub>2</sub> emissions in East and Southeast Asian countries because FDI inflow in these countries is highest among other Asian sub-panels. Section 2.3 will discuss the data source and descriptive statistics. Sections 2.4 outlined methodologies and the conceptual framework used in this chapter and section 2.5 will

be devoted to empirical results and discussion and, lastly chapter ends with conclusion and policy implications

### **2.3: Data source and Descriptive statistics**

This chapter tries to analyse the impact of FDI on environmental degradation by incorporating energy consumption, economic growth and trade openness in the CO<sub>2</sub> function. A balanced panel data from 1994 to 2014 is used in this study. The annual data for CO<sub>2</sub> emissions measured in metric tons per capita; FDI in per cent of GDP; Economic growth (Y) as GDP per capita in constant 2010 US\$; Trade openness (TO) as per cent of GDP and Energy consumption (EC) in kg of oil equivalent per capita are extracted from the World Bank's World Development Indicators database. All the variables are transformed into natural log form, in order to interpret the coefficient estimates as the elasticity's of the response variable (CO<sub>2</sub> emissions) with respect to the independent variables (Y and EC) except TO and FDI (as these variables are already expressed in percentage). Y and EC is used in the CO<sub>2</sub> emission model because they were considered as major determinants of CO<sub>2</sub> emission by different studies, such as Ang (2007), Hossain (2011), Pao and Tsai (2011a,b), Al-Mulali and Sab (2012), which found linear relationships between the variables. The specific countries selected for the chapter and the timeframe was dictated by data availability and the need for a balanced panel, therefore the database is selected to get the maximum number of observations depending on the availability of data. These include sub regions of Asian countries: (i) West Asia consisting of seven countries (Bahrain, Israel, Jordan, Saudi Arabia, Turkey, United Arab Emirates and Oman); (ii) Central Asia consisting of five countries (Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan); (iii) East Asia consisting of five countries (China, Japan, Mongolia, Hong Kong and Korea Republic); (iv) South Asia consisting of six countries (Bangladesh, India, Pakistan, Sri Lanka, Nepal and Iran); (v) Southeast Asian panel consisting of six countries (Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam) are taken as the sample of this chapter<sup>7</sup>.

Table 2.1 presents the descriptive statistics for all the variables used in the chapter. The common summary statistics contains the mean, standard deviation and coefficient of variation of each series. According to these statistics result, CO<sub>2</sub> emissions are measured in metric tons, and statistics reveal that the mean of CO<sub>2</sub> emissions is recorded highest for West Asian countries followed by East, Central, Asian panel and Southeast Asian countries at 2.30, 1.84,

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<sup>7</sup> We have also taken all Asian countries together as panel to analysis its effect on Asian panel

1.20, 1.20 and 0.94 metric tons per capita, respectively. Further it is also noted that Asian panel is most volatile in releasing CO<sub>2</sub> metric tons per capita; it has the highest coefficient of variation of 1.12, followed by Central, Southeast, West, East Asian countries. It implies that countries in the early stages of growth, such as those from the Asian panel and Central Asian countries, pollute more.

**Table 2.1 Summary statistics by sub panels**

| Panels         | Statistics               | CO <sub>2</sub> emissions | EC   | Y    | TO     | FDI   |
|----------------|--------------------------|---------------------------|------|------|--------|-------|
|                | Mean                     | 1.20                      | 7.29 | 8.39 | 80.87  | 4.14  |
| Asian Panel    | Std. deviation           | 1.35                      | 1.09 | 1.45 | 71.63  | 6.05  |
|                | Coefficient of variation | 1.12                      | 0.15 | 0.17 | 0.88   | 1.45  |
|                |                          |                           |      |      |        |       |
|                | Mean                     | 2.30                      | 8.20 | 9.70 | 4.30   | 3.34  |
| West Asia      | Std. deviation           | 0.79                      | 0.88 | 0.83 | 0.41   | 4.41  |
|                | Coefficient of variation | 0.34                      | 0.10 | 0.08 | 0.09   | 1.32  |
|                |                          |                           |      |      |        |       |
|                | Mean                     | 1.20                      | 7.20 | 7.32 | 4.31   | 5.01  |
| Central Asia   | Std. deviation           | 1.25                      | 0.99 | 0.97 | 0.36   | 4.11  |
|                | Coefficient of variation | 1.04                      | 0.13 | 0.13 | 0.08   | 0.82  |
|                |                          |                           |      |      |        |       |
|                | Mean                     | 1.84                      | 7.69 | 9.22 | 104.41 | 6.89  |
| East Asia      | Std. deviation           | 0.45                      | 0.57 | 1.28 | 106.39 | 10.11 |
|                | Coefficient of variation | 0.24                      | 0.07 | 0.13 | 1.01   | 1.46  |
|                |                          |                           |      |      |        |       |
|                | Mean                     | -0.35                     | 6.17 | 7.09 | 37.42  | 0.90  |
| South Asia     | Std. deviation           | 1.23                      | 0.79 | 0.84 | 12.64  | 0.77  |
|                | Coefficient of variation | -3.51                     | 0.12 | 0.11 | 0.33   | 0.85  |
|                |                          |                           |      |      |        |       |
|                | Mean                     | 0.94                      | 7.07 | 8.34 | 130.10 | 5.33  |
| Southeast Asia | Std. deviation           | 0.96                      | 0.89 | 1.19 | 80.89  | 5.99  |
|                | Coefficient of variation | 1.02                      | 0.12 | 0.14 | 0.62   | 1.12  |

Source: Author's calculation (2017)

Based on the aggregate energy consumption measured in kg of oil equivalent per capita, it can be seen that mean energy consumption is recorded highest for West Asia, followed by East, Asian panel, Central and Southeast Asia. It can also be seen that Asian panel are more volatile as it records the highest coefficient of variation. A similar pattern exists for the economic

growth, where the West Asian countries' average economic growth is recorded highest compared to East, Asian panel, Southeast, Central and South Asian countries, respectively.

On average trade openness measured as a percentage of GDP, it can be noticed from the Table 2.1 that Southeast Asian countries are relatively more open to trade as compared with other Asian countries, whereas for West and Central Asia, their trade openness is almost same. Again it is a stylised fact in the literature of international trade which has documented that the countries with more liberalisation are more open to trade (see for example Harrigan, 1996; Chamon and Kremer, 2009).

Finally, the mean FDI inflow measured as a percentage of GDP is recorded highest in East Asia, followed by Southeast, Central, Asian panel, West and South Asian countries. FDI is used as a technology for the growth of the country but depending upon the type of FDI, if the validity of PHH is found to be positive significant it is harmful to a country as it pollutes the environment and increases the CO<sub>2</sub> emissions.

In sum, the summary statistic reveals that the West Asian countries have greater energy consumption, economic growth whereas Southeast Asia is more open to trade followed by other Asian countries panel. These are not surprising findings, the classification of countries into sub-panels based on Asian countries level is crucial in terms of homogenising countries into similar characteristics. It gives a clear distinction amongst the four types of countries based on summary statistics by panel of the four variables. This will ensure that a particular Asian classified country will not be dictating the results and clear comparison of the effect of energy consumption, economic growth, trade openness and FDI inflow on carbon dioxide emissions can be undertaken for panel country at different stages of development.

## **2.4: Empirical model and methodology**

The following is the form of proposed model

$$CO_2 = f(FDI, Y, EC, TO) \quad (2.1)$$

Equation (2.1) states that foreign direct investment (FDI), economic growth (Y), energy consumption (EC), and trade openness (TO) can potentially determine CO<sub>2</sub> emissions. There are a number of studies (Ang, 2007; Hossain, 2011; Pao and Tsai, 2011a, b), that found a linear relationship between energy consumption, economic growth and CO<sub>2</sub> because they were considered as main determinant of CO<sub>2</sub> emissions. However there were some studies such as Wang et al. (2013); Esteve and Tamarit (2012) that found a non-linear relationship between

economic growth, energy consumption and CO<sub>2</sub> emissions. FDI is used in this chapter as a determinant of CO<sub>2</sub> emission which is in line with following studies (Pao and Tsai, 2011b and Al-Mulali, 2012) that utilised it as a major determinant of pollution in their CO<sub>2</sub> emission models. Following this argument, to analyse the relationship between carbon dioxide and its determinants for sub-regions of Asian panel countries, Equation (2.1) written in panel model form as follows:

$$CO_{2it} = \pi_0 + \pi_1 FDI_{it} + \pi_2 Y_{it} + \pi_3 EC_{it} + \pi_4 TO_{it} + \pi_5 DV + \mu_{it} \quad (2.2)$$

where  $\pi$ 's represent the regression coefficient;  $i$  represents country (in this study, we have 29 countries);  $t$  represents time (time frame is 1994-2014); CO<sub>2</sub> is the natural log carbon emissions measured in metric tons per capita; FDI is inflow as a percentage of GDP;  $Y$  is the log of per capita real GDP measured in constant 2010 US\$;  $EC$  is the log of the per capita energy consumption in kg of oil equivalent per capita and  $TO$  represents the trade openness, measured as exports plus imports as percentage of GDP. The long-run parameters for CO<sub>2</sub> emissions with respect to FDI, economic growth, energy consumption, and trade openness are  $\pi_1, \pi_2, \pi_3$  and  $\pi_4$ . The expected sign for  $\pi_2$  &  $\pi_3$  is positive while  $\pi_1$  and  $\pi_4$  can be either positive or negative.  $DV$  is dummy variables; dummy variables (dummy) is created to capture the effect of international and national policy changes that have been made in 1997 on CO<sub>2</sub> emissions. Here, Dummy = 0, when there is no changes in climate policy while Dummy = 1, when changes in climate policy. If the dummy variables are found significant and positive then climate policy adopted national and internationally has a positive effect on CO<sub>2</sub> emissions otherwise climate policy will reduce carbon emissions in Asian countries, therefore coefficient  $\pi_5$  may be positive or negative depending on the countries adoption of climate policy.

#### 2.4.1: Panel unit root tests

This study propose two kinds of panel unit root tests to test the stationary properties of panel data. These tests allow individual unit root processes autoregressive coefficients to vary across cross-sections. The Im–Pesaran–Shin (IPS) and Augmented Dickey Fuller (ADF) fisher tests assume an individual unit root process across the cross-section for the null of a unit root to obtain panel results. The application of these unit root tests is essential in identifying the order of integration of the variables, therefore it is an important issue to be considered as it determines the selection of the models for empirical analysis. The null hypothesis for this test can be shown

as  $H_0: \rho_i = 1$  whereas alternate hypothesis as  $H_1: \rho_i < 1$  which means variables contains and does not contain panel unit root respectively. For instance, all the variables are non-stationary at levels and stationary at their first-order differentials, if all of the variables are integrated in the order of 1 or I (1).

#### 2.4.2: Panel Cointegration test

The study employ panel cointegration techniques to examine the existence of a long run relationship between CO<sub>2</sub> emissions, FDI, economic growth, energy consumption, and trade openness in the sub-regions of Asian countries.

This study apply residuals-based test for cointegration methodology which is proposed and developed by Pedroni (1999, 2004). Pedroni (2004) proposes seven statistics distributed on two sets of cointegration tests that allow for heterogeneity in the intercepts and trend coefficients across countries. In time series analysis, similar residuals-based test for cointegration is proposed by Engle and Granger (1987). To implement Pedroni's cointegration test, Pedroni (1999) utilizes the two-step regression framework to test for panel cointegration. Therefore this study first estimate the following panel regression model and save the residuals:

$$y_{i,t} = \gamma_i + \sigma_i t + \beta_{1i} Z_{1i,t} + \beta_{2i} Z_{2i,t} \dots \dots \dots \beta_{mi} Z_{mi,t} + \mu_{i,t} \quad (2.3)$$

Here  $y_{i,t}$  are the dependent variable, while  $Z_{1i,t}$  are the independent variables assumed to be integrated of order I (1);  $\mu_{i,t}$  are the residuals derived from the above panel regression;  $\gamma_i$  and  $\beta_{1i} \beta_{2i} \dots \beta_{mi}$  are the intercept term and slope coefficient that vary across every individual member of the panel respectively. To test whether or not the residuals are stationary, the study present the following panel regression model with the saved residuals. Under the null hypothesis of no cointegration, the residuals are stationary, I (0) or not. The estimated residuals are defined as follows;

$$\Delta \mu_{i,t} = \delta_i \mu_{i,t-1} + \varepsilon_{i,t} \quad (2.4)$$

$$\Delta \mu_{i,t} = \delta_i \mu_{i,t-1} + \sum_{j=1}^{\delta_i} \theta_{ij} \Delta \mu_{i,t-j} + \omega_{i,t} \quad (2.5)$$

Here  $\mu_{i,t}$  are the residuals;  $\Delta$  is the first difference operator. The residuals  $\varepsilon_{i,t}$  and  $\omega_{i,t}$  are assumed to be normally distributed and white noise. Pedroni (2004) suggested different statistic to examine the null hypothesis of no cointegration. First four tests are panel v statistic, panel rho-statistic, PP statistic and ADF statistic. Moreover, these statistics are classified on within



dimension and take into account common autoregressive coefficient across countries. The second group of test includes group rho-statistic, group PP statistic and group ADF statistic. Based on the individual autoregressive coefficients for each country in the panel, these tests are classified on the between-dimension.

#### **2.4.3: Fully Modified Ordinary least square estimation**

An important inference of an empirical study is to estimate the long-run coefficients of the explanatory variables after it is found that carbon emissions, FDI, economic growth, energy consumption, and trade openness are cointegrated. The OLS estimators of the cointegrated vectors are super-convergent and commonly used ones in a variety of literature. However, the dynamic ordinary least squares (DOLS) and the fully modified ordinary least squares (FMOLS) estimators have been recently preferred to the OLS estimator (Lee, 2007). To examine the long run elasticities for each explanatory variable, this study employ the group mean FMOLS estimator. FMOLS that was initially suggested by Philips and Hansen (1990), is more powerful than the OLS because it corrects for both endogeneity bias and serial correlation. One of the advantages of using FMOLS is that long run correlation problem gets eliminated. Phillips and Moon (1999) showed that the FMOLS estimator appears to outperform both estimators while the OLS technique exhibits small sample bias. It is unbiased. Kao and Chiang (2001) also showed that FMOLS techniques led to normally distributed estimators. Using asymptotic Chi-square statistical inference, it has full asymptotic efficiency allowing for standard Wald tests.

#### **2.5: Results and Discussion**

Prior to testing cointegration, two panel unit root tests such as IPS and ADF fisher are applied at level and first difference to check the integrated properties of the variables. The results of the unit root test are summarized in Tables 2.2-2.7 for the six different sub-regions of Asian countries namely:- Asian panel, West Asia, Central Asia, East Asia, South Asia and Southeast Asia. In all the six panels it can be seen that FDI is stationary at its level form. The IPS results show that all the variables are stationary at the first difference. Likewise, the ADF-Fisher tests also show that variables are non-stationary at levels and stationary at first difference, as we reject the null hypothesis at the 1 per cent significance level implying that CO<sub>2</sub> emissions, FDI, Y, EC and TO belong to I (1) process. Based on these results, all the selected variables are stationary at first difference. Thus, using the Pedroni cointegration test, this study proceed to analyse the existence of cointegration.

**Table 2.2: Panel unit root analysis for Asian panel**

| Variables          | at level  |                   | at 1st difference |                   |
|--------------------|-----------|-------------------|-------------------|-------------------|
|                    | Intercept | Intercept & trend | Intercept         | Intercept & trend |
| IPS unit root test |           |                   |                   |                   |
| CO <sub>2</sub>    | -0.38     | 0.16              | -13.60*           | -14.19*           |
| FDI                | -5.62*    | -7.74*            | -19.76*           | -15.36*           |
| Y                  | 6.41      | -0.73             | -9.96*            | -8.34*            |
| EC                 | 1.31      | -2.72*            | -15.34*           | -13.17*           |
| TO                 | 0.15      | -3.33*            | -17.73*           | -14.86*           |
| ADF unit root test |           |                   |                   |                   |
| CO <sub>2</sub>    | 70.96     | 62.23             | 292.57*           | 276.05*           |
| FDI                | 135.84*   | 161.63*           | 409.15*           | 296.10*           |
| Y                  | 37.51     | 64.31             | 210.48*           | 172.63*           |
| EC                 | 59.43     | 99.49*            | 316.08*           | 257.13*           |
| TO                 | 63.38     | 95.10*            | 364.85*           | 285.92*           |

Note: The unit root tests were done with individual trends and intercept for each variable lag length were selected automatically using the Schwarz Information Criteria (SIC). \* indicate statistical significance at the 1 per cent level.

Source: Author's calculation (2017)

**Table 2.3: Panel unit root analysis for West Asia**

| Variables          | at level  |                   | at 1st difference |                   |
|--------------------|-----------|-------------------|-------------------|-------------------|
|                    | intercept | Intercept & trend | intercept         | Intercept & trend |
| IPS unit root test |           |                   |                   |                   |
| CO <sub>2</sub>    | -1.66**   | 0.16              | -8.39*            | -8.19*            |
| FDI                | -2.36*    | -2.91*            | -8.61*            | -6.26*            |
| Y                  | 0.62      | -0.04             | -4.07*            | -2.61*            |
| EC                 | 0.62      | -1.17             | -7.70*            | -6.55*            |
| TO                 | 1.38      | -1.10             | -7.59*            | -6.32*            |
| ADF unit root test |           |                   |                   |                   |
| CO <sub>2</sub>    | 21.73***  | 13.36             | 86.49*            | 77.22*            |
| FDI                | 26.91**   | 32.50*            | 85.40*            | 59.57*            |
| Y                  | 10.58     | 11.59             | 43.30*            | 30.90*            |
| EC                 | 11.46     | 19.18             | 78.77*            | 62.61*            |
| TO                 | 10.16     | 21.103***         | 76.51*            | 59.28*            |

Note: The unit root tests were done with individual trends and intercept for each variable lag length were selected automatically using the Schwarz Information Criteria (SIC). \*, \*\* & \*\*\* indicate statistical significance at the 1, 5 and 10 per cent levels.

Source: Author's calculation (2017)

**Table 2.4: Panel unit root analysis for Central Asia**

| Variables          | at level  |                   | at 1stdifference |                   |
|--------------------|-----------|-------------------|------------------|-------------------|
|                    | intercept | Intercept & trend | intercept        | Intercept & trend |
| IPS unit root test |           |                   |                  |                   |
| CO <sub>2</sub>    | 0.61      | -0.52             | -3.59*           | -3.98*            |
| FDI                | -3.06*    | -2.54*            | -12.34*          | -9.07*            |
| Y                  | 2.35      | -1.23             | -5.31*           | -3.18*            |
| EC                 | 1.08      | -0.28             | -5.43*           | -6.06*            |
| TO                 | -0.77     | -1.47***          | -6.57*           | -5.21*            |
| ADF unit root test |           |                   |                  |                   |
| CO <sub>2</sub>    | 10.06     | 10.63             | 34.74*           | 34.48*            |
| FDI                | 26.08*    | 21.41**           | 105.86*          | 70.83*            |
| Y                  | 5.34      | 17.97***          | 45.29*           | 27.63*            |
| EC                 | 5.01      | 11.51             | 45.66*           | 46.55*            |
| TO                 | 12.63     | 17.34***          | 55.54*           | 41.87*            |

Note: The unit root tests were done with individual trends and intercept for each variable lag length were selected automatically using the Schwarz Information Criteria (SIC). \*, \*\* & \*\*\* indicate statistical significance at the 1, 5 and 10 per cent level.

Source: Author's calculation (2017)

**Table 2.5: Panel unit root analysis for East Asia**

| Variables          | at level  |                   | at 1st difference |                   |
|--------------------|-----------|-------------------|-------------------|-------------------|
|                    | Intercept | Intercept & trend | Intercept         | Intercept & trend |
| IPS unit root test |           |                   |                   |                   |
| CO <sub>2</sub>    | 0.56      | -0.49             | -3.38*            | -5.19*            |
| FDI                | -0.90     | -4.76*            | -6.54*            | -5.43*            |
| Y                  | 0.87      | -0.55             | -4.87*            | -4.53*            |
| EC                 | -0.26     | -4.31*            | -5.72*            | -4.18*            |
| TO                 | -0.09     | -0.37             | -7.36*            | -6.69*            |
| ADF unit root test |           |                   |                   |                   |
| CO <sub>2</sub>    | 10.54     | 20.19**           | 35.86*            | 43.61*            |
| FDI                | 18.80**   | 39.11*            | 56.90*            | 44.41*            |
| Y                  | 19.88     | 11.71             | 42.12*            | 38.07*            |
| EC                 | 19.10**   | 36.20*            | 49.09*            | 36.41*            |
| TO                 | 10.79     | 11.31             | 62.15*            | 51.89*            |

Note: The unit root tests were done with individual trends and intercept for each variable lag length were selected automatically using the Schwarz Information Criteria (SIC). \*, \*\* & \*\*\* indicate statistical significance at the 10, 5 and 1 per cent level.

Source: Author's calculation (2017)

**Table 2.6: Panel unit root analysis for South Asia**

| Variables          | at level  |                   | at 1st difference |                   |
|--------------------|-----------|-------------------|-------------------|-------------------|
|                    | Intercept | Intercept & trend | Intercept         | Intercept & trend |
| IPS unit root test |           |                   |                   |                   |
| CO <sub>2</sub>    | 0.57      | 1.57              | -7.67*            | -7.36*            |
| FDI                | -2.15**   | -1.71**           | -7.90*            | -6.22*            |
| Y                  | 5.83      | 0.46              | -2.88*            | -3.15*            |
| EC                 | 2.98      | 0.77              | -8.64*            | -8.33*            |
| TO                 | -1.41***  | -2.57*            | -10.68*           | -8.72*            |
| ADF unit root test |           |                   |                   |                   |
| CO <sub>2</sub>    | 15.54     | 5.41              | 70.59*            | 63.02*            |
| FDI                | 23.60**   | 20.76***          | 73.75*            | 54.27*            |
| Y                  | 0.82      | 9.56              | 30.08*            | 30.04*            |
| EC                 | 5.59      | 9.41              | 79.63*            | 70.26*            |
| TO                 | 22.73**   | 24.54**           | 99.36*            | 74.79*            |

Note: The unit root tests were done with individual trends and intercept for each variable lag length were selected automatically using the Schwarz Information Criteria (SIC). \*, \*\* & \*\*\* indicate statistical significance at the 1, 5 and 10 per cent level.

Source: Author's calculation (2017)

**Table 2.7: Panel unit root analysis for Southeast Asia**

| Variables          | at level  |                   | at 1st difference |                   |
|--------------------|-----------|-------------------|-------------------|-------------------|
|                    | intercept | Intercept & trend | intercept         | Intercept & trend |
| IPS unit root test |           |                   |                   |                   |
| CO <sub>2</sub>    | -0.74     | -0.30             | -7.00*            | -6.64*            |
| FDI                | -4.15*    | -5.31***          | -9.18*            | -7.55*            |
| Y                  | 4.71      | -0.33             | -5.34*            | -5.24*            |
| EC                 | -1.38***  | -1.09             | -6.60*            | -4.29*            |
| TO                 | 0.94      | -1.84**           | -7.52*            | -6.41*            |
| ADF unit root test |           |                   |                   |                   |
| CO <sub>2</sub>    | 13.07     | 12.61             | 64.87*            | 57.70*            |
| FDI                | 40.44*    | 47.82*            | 87.22*            | 67.01*            |
| Y                  | 0.87      | 13.46             | 49.67*            | 45.99*            |
| EC                 | 18.26     | 23.17**           | 62.91*            | 41.28*            |
| TO                 | 7.30      | 21.12**           | 72.27*            | 62.45*            |

Note: The unit root tests were done with individual trends and intercept for each variable lag length were selected automatically using the Schwarz Information Criteria (SIC). \*, \*\* & \*\*\* indicate statistical significance at the 1, 5 and 10 per cent level.

Source: Author's calculation (2017)

The results of the Pedroni (1999, 2004) cointegration tests for Asian panel are displayed in Table 2.8 show that the null hypothesis of no cointegration can be rejected in most cases. Specifically, 4 out of 7 statistic tests reject the null hypothesis of no cointegration at the 1 per cent level. Similarly, this study found the result for other panel groups such as West, Central, East, South and Southeast Asian panel which is presented in Table 2.9. The result shows that the null hypothesis for no cointegration can be rejected in 4 out of 7 statistics.

**Table 2.8: Pedroni panel cointegration test**

| Tests               | Asian Panel |       |
|---------------------|-------------|-------|
|                     | Statistic   | Prob. |
| Panel v Statistic   | -1.57       | 0.94  |
| Panel rho Statistic | 1.23        | 0.89  |
| Panel PP Statistic  | -4.41       | 0.00* |
| Panel ADF Statistic | -5.46       | 0.00* |
| Group rho Statistic | 3.29        | 0.99  |
| Group PP-Statistic  | -7.83       | 0.00* |
| Group ADF-Statistic | -7.48       | 0.00* |

Note: Lag length and bandwidth are selected by Schwarz Information Criterion (SIC) and the Bartlett kernel Newey-West estimator. \*indicate statistical significance at 1 per cent level. Prob. Probability value. Source: Author's calculation (2017)

**Table 2.9: Pedroni cointegration test (Sub-regional countries)**

| Sub Panels   | West Asia  |         | Central Asia |         | East Asia  |        | South Asia |        | Southeast Asia |       |
|--------------|------------|---------|--------------|---------|------------|--------|------------|--------|----------------|-------|
| Tests        | Statistics | Prob.   | Statistics   | Prob.   | Statistics | Prob.  | Statistics | Prob.  | Statistics     | Prob. |
| P. v-Stats   | -1.96      | 0.97    | 1.62         | 0.05*** | -1.45      | 0.92   | -0.86      | 0.80   | -1.07          | 0.85  |
| P. rho Stats | 1.87       | 0.96    | -0.14        | 0.44    | 0.36       | 0.64   | 1.15       | 0.87   | 0.60           | 0.72  |
| P.PP Stats   | -2.09      | 0.01*   | -1.44        | 0.07*** | -2.31      | 0.01** | -2.04      | 0.02** | -7.16          | 0.00* |
| P.ADF stats  | -2.70      | 0.00*   | -1.35        | 0.08*** | -2.33      | 0.00*  | -1.98      | 0.02** | -6.42          | 0.00* |
| G. rho-Stats | 2.80       | 0.99    | 0.57         | 0.71    | 2.21       | 0.98   | 2.12       | 0.98   | 1.80           | 0.96  |
| G.PP-Stats   | -1.55      | 0.06*** | -4.32        | 0.00*   | -4.13      | 0.00*  | -2.38      | 0.00*  | -4.80          | 0.00* |
| G. ADF stats | -1.61      | 0.05*** | -3.57        | 0.00*   | -3.68      | 0.00*  | -1.87      | 0.03** | -6.74          | 0.00* |

Note: Lag length and bandwidth are selected by Schwarz Information Criterion (SIC) and the Bartlett kernel Newey-West estimator. Where P is Panel, G is Group & Stats is statistic. \*, \*\* & \*\*\* indicate statistical significance at the 1, 5 and 10 per cent levels. Prob. Probability value. Source: Author's calculation (2017)

Therefore, carbon emissions, FDI, economic growth, energy consumption and trade openness are cointegrated. By using the group mean panel FMOLS, the study estimate the long run

coefficients of CO<sub>2</sub> emissions and its determinants. The results of FMOLS are reported in Table 2.10 & 2.11.

## 2.6: Long run results

The FMOLS results of the Asian panel are presented in Table 2.10 reveals that consumption of energy and economic growth positively and significantly affects CO<sub>2</sub>. This implies that 1 per cent increase in energy consumption and economic growth increases environmental emissions by 0.98 per cent and 0.14 per cent respectively. This results was consistent with the outcome of a number of previous studies that also found a long relationship between CO<sub>2</sub> emission and its main determinants such as Tang and Tan (2015), Linh and Lin (2014) and Tamazian and Rao (2010) who suggested energy consumption and economic growth significantly contributed to CO<sub>2</sub> emissions. TO and FDI has a statistically insignificant but has negative and positive impact on the CO<sub>2</sub> emissions respectively.

**Table 2.10: Long run estimates for Asian panel**

| Dependent emissions | Variable:CO <sub>2</sub> | Coefficient | Prob. |
|---------------------|--------------------------|-------------|-------|
| FDI                 |                          | 0.00        | 0.68  |
| Y                   |                          | 0.14        | 0.00* |
| EC                  |                          | 0.98        | 0.00* |
| TO                  |                          | 0.00        | 0.25  |
| DV                  |                          | 0.01        | 0.61  |

Note: \*indicate statistical significance at 1 per cent level.

Source: Author's calculation (2017)

The FMOLS result for Asian panel sub-regions countries is reported in Table 2.11. In the West Asian panel, the elasticity of CO<sub>2</sub> emissions with respect to energy consumption is 0.87. This implies that increases in energy consumption increases carbon emissions in the West Asian panel. These results were similar to what was found by Kasman and Duman (2015), Al-Mulali (2012), Al-Mulali and Sheau-Ting (2014), and Halicioglu (2009). However, other scholars found a negative relationship between the two variables such as Farhani et al. (2014), Kohler (2013) and Shahbaz et al. (2013a, b), Hossian (2011), Jayanthakumaran et al. (2012), Sulaiman et al. (2013) and Jebli et al. (2016). Also, trade openness and FDI are found to have statistically insignificant but positive effects on CO<sub>2</sub> emissions whereas economic growth was observed to have negative impact on carbon emissions.

In the Central Asian panel, similar results were found that economic growth and energy consumption has statistically significant positive effect on CO<sub>2</sub> emissions at 1 per cent level of

significance. Thus imply that a 1 per cent increase in energy consumption and economic growth increases environmental pollution by 0.83 per cent and 0.09 per cent, respectively. These results are in consistence with the findings of Linh and Lin (2014), Bento and Moutinho (2016), Al-Mulali and Ozturk (2016), Al-Mulali et al. (2015). However, the increase in trade has a negative relationship and significantly effects CO<sub>2</sub> emissions. Some studies have also reached the same conclusion, but other studies found that the relationship between the two variables was positive or insignificant.

**Table 2.11: Long run results for Asian sub panels**

| Sub regions | West Asia |       | Central Asia |         | East Asia |         | South Asia |       | Southeast Asia |         |
|-------------|-----------|-------|--------------|---------|-----------|---------|------------|-------|----------------|---------|
|             | Coeff.    | Prob. | Coeff.       | Prob.   | Coeff.    | Prob.   | Coeff.     | Prob. | Coeff.         | Prob.   |
| FDI         | 0.00      | 0.95  | -0.00        | 0.36    | 0.01      | 0.00*   | 0.00       | 0.80  | -0.02          | 0.00*   |
| Y           | -0.10     | 0.39  | 0.09         | 0.00*   | 0.44      | 0.00*   | 0.52       | 0.00* | 0.30           | 0.05*** |
| EC          | 0.87      | 0.00* | 0.83         | 0.00*   | 0.55      | 0.00*   | 0.76       | 0.00* | 1.13           | 0.00*   |
| TO          | 0.00      | 0.37  | 0.01         | 0.05*** | -0.01     | 0.00*   | 0.001      | 0.71  | -0.002         | 0.02**  |
| DV          | 0.02      | 0.53  | 0.01         | 0.58    | -0.07     | 0.06*** | 0.04       | 0.45  | -0.05          | 0.48    |

Note: \*, \*\* & \*\*\* indicate statistical significance at the 1, 5 and 10 per cent level. Dependent Variable: CO<sub>2</sub> emissions, *Coeff.* Coefficient, *Prob.* Probability value. Source: Author's calculation (2017).

In the East Asian panel, the results for the long-run relationship between FDI by source and CO<sub>2</sub> emissions, increase in FDI inflow stimulate the level of emissions. The sign of the FDI coefficient is positive and statistically significant at 1 per cent level. Thus, CO<sub>2</sub> emissions increase by 0.01 per cent globally for every 1 per cent increase in FDI, which supports the PHH. The implication is that foreign investors use worse management practices and shift dirty goods in the host countries resulting in increasing the level of environmental pollution in the host countries. This increase in carbon emissions, which also implies that higher the FDI inflow, higher will be the pollution since FDI inflow in East Asia is 60 per cent according to AEIR (2016). Similar results were reported in Kiviyiro and Arminen (2015) which suggested that FDI increases CO<sub>2</sub> emissions in sub-Saharan Africa because of the low-quality technology used in production and the related environmental regulations. Jiang (2015) also showed that FDI deteriorates the environmental quality by increasing CO<sub>2</sub> emissions in 110 developed & developing countries and China respectively. By contrast, Tamazian and Rao (2010) showed that FDI decreases CO<sub>2</sub> emissions in the case of 24 transition economies.

Furthermore, consumption of energy and economic growth increases pollution by its positive effect on CO<sub>2</sub> emissions in the long run. The increase in energy consumption and economic

growth by 1 per cent will increase CO<sub>2</sub> emissions by 0.55 per cent and 0.44 per cent respectively. It can also observe that dummy variables which take into account the policy changes that have been made during 1994-2014 show that implementation of policy at a national and international level were able to reduce CO<sub>2</sub> emissions in East Asian countries which has a negative effect on carbon emissions. Meaning there by that a 1 per cent change in policy level reduces CO<sub>2</sub> emissions by 0.07 per cent, similarly trade also show a negative sign indicating a decrease in CO<sub>2</sub> emissions in East Asia.

Similar results were found for South Asia that energy consumption and economic growth has a statistically significant positive effect on CO<sub>2</sub> emissions at 1 per cent level of significance. It implies that a 1 per cent increase in energy consumption and economic growth increases environmental pollution by 0.76 per cent and 0.52 per cent, respectively.

Lastly, in the Southeast Asian panel, the relationship between FDI and carbon emissions is found to be statistically significant and negatively related. FDI is negatively linked to CO<sub>2</sub> emissions and statistically significant at 1 per cent level significance. Thus, CO<sub>2</sub> emissions decline by 0.02 per cent globally for every 1 per cent increase in FDI. Since the FDI inflow in these countries is 24 per cent lower than East Asia which is almost 60 per cent, therefore we can conclude that lower the FDI, least will be the pollution. This finding is consistent with the Lindert and Williamson (2007) for the less developed economy thereby means that the foreign investor export pollution-free technology to the host country, resulting in pollution free environment. In one of the studies, Chandran and Tang (2013) have investigated the effect of FDI on CO<sub>2</sub> emissions over the period 1971-2008 for ASEAN-5 economies using cointegration and Granger test. Their result found that FDI is not significant. Moreover, energy consumption stimulates the level of carbon emissions, unlike the earlier Asian panels. It is also seen that economic growth has a statistically significant positive impact on CO<sub>2</sub> emissions while trade openness has a statistically significant negative impact on CO<sub>2</sub> emissions. Therefore energy consumption is an important contributor to environmental pollution in all the panels.

Summarizing the above results, the main findings are as follows. First, This results show that energy consumption is positive and statistically significant at 1 per cent level of significance in all the six panels' namely Asian panel, West Asia, Central Asia, East Asia, South Asia and Southeast Asian panel. It means energy consumption is an important determinant of carbon emissions in all the panels.

Secondly, economic growth is found to have a statistically significant effect on the CO<sub>2</sub> emissions except for West Asian panel. However, it has a positive effect on CO<sub>2</sub> emissions.



Thirdly trade of goods and services has a statistically insignificant impact on CO<sub>2</sub> emissions, meaning that trade openness is not a significant determinant of CO<sub>2</sub> emissions in Asian panel, West Asia and South Asian panels. However, in the Central, East and Southeast Asian panel there is a statistically significant negative relationship between trade openness and CO<sub>2</sub> emissions. This result is inconsistent with the line of Hecksher-Ohlin trade theory which predicts greater opportunity of production and consumption of goods and services leading to greater environmental pollution.

Fourthly and lastly, it has been found that the impact of FDI on the two panels such as East and Southeast Asia panel are statistically significant with positive and negative effect on CO<sub>2</sub> emissions respectively. Whereas in West and South Asia it is a positive but statistically insignificant relationship between FDI and carbon emissions while in the Central panel it shows negative relation. Therefore, the empirical results reject the PHH in the Southeast Asian panel countries whereas it accepts the validity of the PHH in East Asian countries.

## **2.7: Conclusion and policy implications**

The purpose of this chapter is to analyse the existence of PHH for the Asian panel consisting of 29 countries and for five sub-regional countries of Asian based panels (namely West Asia, Central Asia, East Asia, South Asia and Southeast Asia) throughout 1994-2014. Before testing for any causal relationship among the variables, panel unit root tests and panel cointegration tests are applied. To achieve the goal of this study, two different panel unit root tests of ADF chi square and IPS have been used. The empirical evidence reveals that all the variables are integrated of order one or I(1). Also panel cointegration tests (Pedroni, 1999; 2004) have also been used. The outcome from the Pedroni cointegration confirmed the long-run relationship between CO<sub>2</sub> emissions, energy consumption, economic growth, FDI and trade openness. Moreover, the group means FMOLS results revealed that energy consumption and economic growth are two of the main determinants of CO<sub>2</sub> in the Asian panel. While the other variables namely trade openness have statistically insignificant effects on CO<sub>2</sub> emissions in Asian, West and South panels whereas FDI has statistically insignificant impact on CO<sub>2</sub> emissions in Asian panel, West, Central and South Asia. It is also noted that economic growth has a statistically significant positive impact on CO<sub>2</sub> emissions for the all the panels, but it is statistically insignificant in the West Asia though it has negative effect on CO<sub>2</sub> emissions.

Furthermore, trade openness has a statistical insignificant impact on CO<sub>2</sub> emissions in West and South Asian panels though it is positive and negative respectively. In addition, trade

openness only has a statistically significant positive effect in the Central, East and Southeast Asia; this strongly illustrates that trade of goods and services is good for these countries to reduce CO<sub>2</sub> emission.

Finally, FDI is found to have positive and negative effect on CO<sub>2</sub> emissions in East and Southeast Asian panels respectively. FDI reduces CO<sub>2</sub> emissions at every stage of economic growth in Southeast Asian countries, but not in East Asia. This implies that FDI policies in East Asia effect environment pollution, in turn lowering environment quality. Increased FDI mainly in the industrial and production sectors in East Asian countries will result in significant environmental degradation and unsustainability over time due to pollution. This finding is consistent with Tamazian and Rao (2010) who found that increased FDI reduces CO<sub>2</sub> emissions. Tamazian et al. (2009) and List and Co (2000) suggest that by promoting technological innovation, sometimes FDI and economic growth can increase energy efficiency with low CO<sub>2</sub> emissions. The result for the Asian, West, Central and South Asia panel is inconclusive as FDI has a statistically insignificant positive impact on CO<sub>2</sub> emissions in Asian panel, West and South Asia while the FDI has a statistically insignificant negative impact on the CO<sub>2</sub> emissions in Central Asia.

From these finding, appropriate policies have been recommended for West-, Central-, East-, South-, and Southeast Asian countries to exploit FDI and control pollution. First, this study finds that economic growth of Asian panel, Central, East, South and Southeast Asian countries lead to more carbon dioxide emissions. To reduce emissions, these countries need to embrace more energy conservation policies. The second implication derived from this findings on the impact of energy consumption is that energy consumption positively and significantly contributes to carbon emissions in all the panels of Asian countries. With its 4.3 billion inhabitants accounting for 60 per cent of the world population, Asia is the most populous continent. This means they will exert more pressure on the environment, as population and industrial output in these countries expand, leading to more emissions. Here two points can be noted one there should be a proper check on population control or policymakers should enhance the use of alternative source of energy. Third, FDI impedes the environment quality in East Asian countries. As FDI particularly increases pollution, more environmental preservation efforts are needed in East Asia. These countries should encourage the use of environment-friendly technologies to enhance domestic production. The governing bodies should also stop licensing polluting industries such as chemical and pharmaceutical firms, which emit more CO<sub>2</sub> emissions comparatively. Therefore these polluting firms must be regularly assessed for their environmental impact. In addition, increasing public awareness on the effect of hazardous

waste and polluting industries as well as on preserving the environment. Firms must also be up to date using energy-saving technologies. Fourth, the climate policy that has been signed (Kyoto protocol) show that only East Asian countries were able to reduce carbon emissions up to certain extent. Fifth, these countries should utilize policies to encourage inward FDI especially on the services sector rather in polluting firms since it plays an important role in stimulating GDP growth and policies that regulate the FDI- environment relationships and reduce environmental pollution should be enforced in East Asian countries. Since the validity of PHH is proven for East Asian panel.

Finally, FDI improves the environmental quality in Southeast Asian countries. Hence the PHH in the case of Southeast Asian countries is invalid. It shows that developed or Southeast Asian countries could transfer their environment-friendly technologies to developing countries for protecting the environment from degradation. That will increase the environmental quality at the global level and protect environment quality in developing countries.

## **Chapter 3**

### **Economic Growth and Environmental Quality: Some Recent Evidence from Asian Countries.**

#### **3.1: Introduction**

The world today is confronted with the surge in global environmental pollution and maintaining economic development. With the massive increase in the greenhouse gases (GHG) emission, the environment has come to the forefront of the contemporary issues both for developed and developing nations. This has resulted due to the extensive use of natural resources and fossil-fuel to enlarge the production level. Over the decades, the world has experienced significant growth in economic and social development and consequentially moved toward resource and energy-intensive lifestyle. While around 70 per cent of energy demand fulfil by non-renewable energy (World Bank, 2018). Therefore the focus has been given on the role of energy conservation, pollution control and renewable energy to reduce the environmental impact of such a lifestyle. Both unilateral and multilateral attempt have been made by different nations to devise the policies to tackle the issue.

In recent years, an enormous volume of research was conducted to devise the plan for better environmental management. Further, it has attracted the attention of the researcher to investigate the relationship between economic growth, energy consumption and environmental degradation (Salahuddin and Gow, 2014; Salahuddin et al., 2016). Various scenario-based forecasting and empirical analysis have been attempted in different regions and countries. A significant portion of studies aims to test the existence of the Environmental Kuznets curve (EKC) hypothesis. EKC claims the inverted U-shaped association between growth-emissions nexus (Grossman and Krueger, 1991). Enormous empirical studies verify the existence of an inverted U-shaped relationship (Liu et al., 2007; Bilgili et al., 2016; Shahbaz et al., 2017; Fakher, 2019). Many have argued that service sector, the emergence of information-intensive industries, technological innovation, and higher expenditures on the environment played an important role in framing the EKC (Cole, 2004; Grossman and Krueger, 1996; Stern, 2004) describes, the relationship between economic growth and environmental degradation with international trade. However, different sets of policy recommendation have been initiated based on their results for different countries to overcome these environmental issues.

Extensive studies have been conducted to examine the driving factors behind environmental pollution. Given the fact that CO<sub>2</sub> emission is the primary cause of climate change, majority of studies used it as an indicator of environmental pollution. However it is criticized to use it as sole proxy of environmental pollution. Since it ignore other major pollutant which too contributes to environmental deterioration (Al-Mulali et al., 2015b; Wackernagel and Rees, 1998). On the other hand, degradation in mining, forestry land, oil, grazing land and so forth is extremely important. So outcome may be misleading when using CO<sub>2</sub> emissions solely as proxy for environmental pollution. Therefore, one must use inclusive environmental indicator to obtain better understanding between economic growth and environmental damage to the country. For this purpose the study employed ecological footprint (EF) indicator to compute cumulative human pressure on the environment.

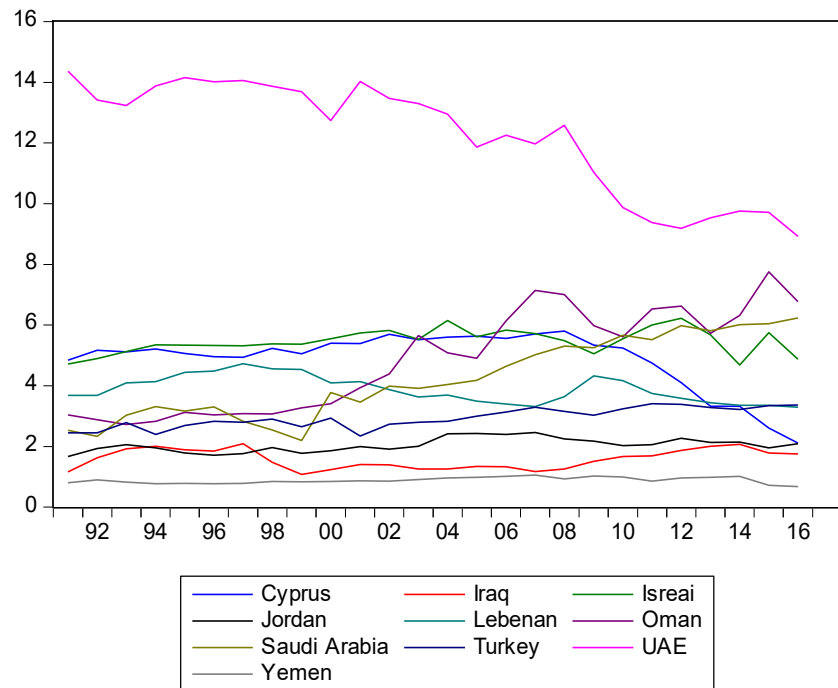
The concept of EF was initially developed by Rees (1992) and later introduced by Wackernagel and Rees (1998). It measures six components: - forest land, built-up land, grazing, cropping, fishing grounds and carbon footprint which includes carbon dioxide (CO<sub>2</sub>) emissions within the carbon footprint<sup>8</sup>. It can be described as pressure of human activity on the nature (Bartelmus, 2008; Kitzes and Wackernagel, 2009). It can be used for policy setting and easy to monitor. It is measured in terms of global hectare of land (bio productive) required for carrying out human activities in a sustainable manner.

On the theoretical background, Asia's EF continues to rise at a faster pace than Earth's bio capacity in these regions and relatively higher than all other regions. Furthermore, EF shows considerable variabilities across Asian region. This is mainly due to sharp increase in population, higher growth of consumption expenditure, and decline in the productive ecological resources along with inadequate resource management, habitat destruction and environmental pollution. Figures. 3.1–3.5 show the EF of considered five Asian sub regions by land use type. Overall rise in Asia's EF is contributed by China (Galli et al., 2012), whereas EF in the West and Central Asia is also showing increasing trend with highest per capita growth than any other region. United Arab Emirates hold the largest average EF at 10.7 global hectares (gha) per person, while Yemen has lowest 1.0 gha per person level, dynamics and population play different roles. West-and Central Asia experienced rapid increase in per capita EF, between 1961 and 2016, it grew by 126 per cent and 146 per cent while population increased

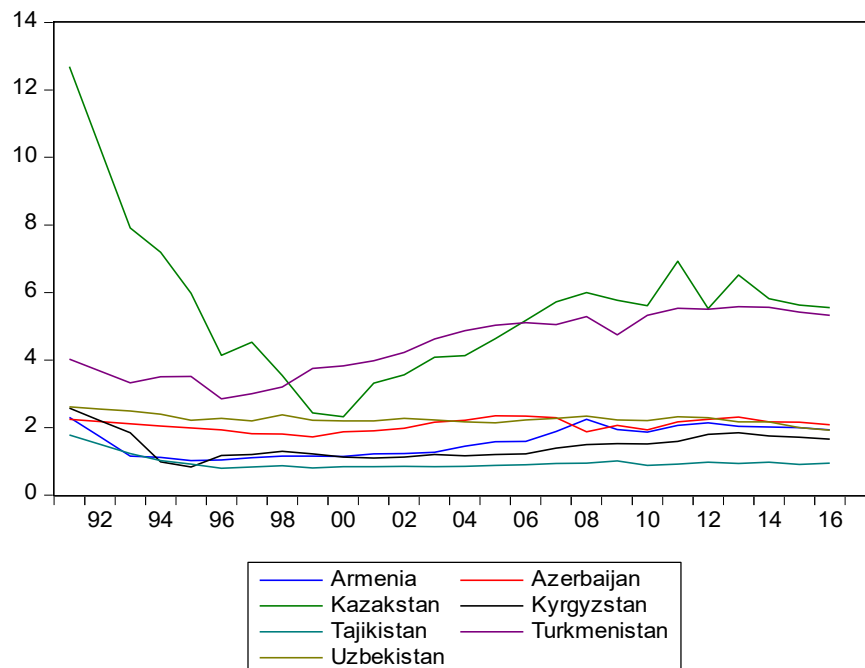
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<sup>8</sup> For more details see Lin et al. (2018)

by 155 per cent and 465 per cent respectively (Lin et al., 2018). This led to the overall EF to be increased by six fold in West and Central Asian regions.

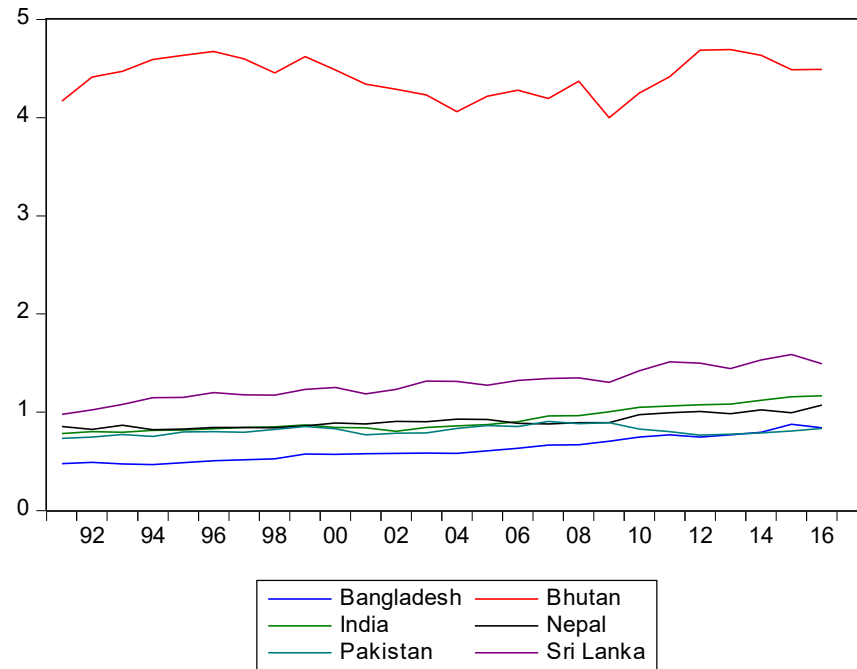


**Figure 3.1: Ecological footprint per capita consumption by West Asia**  
Source: GFN (2019)

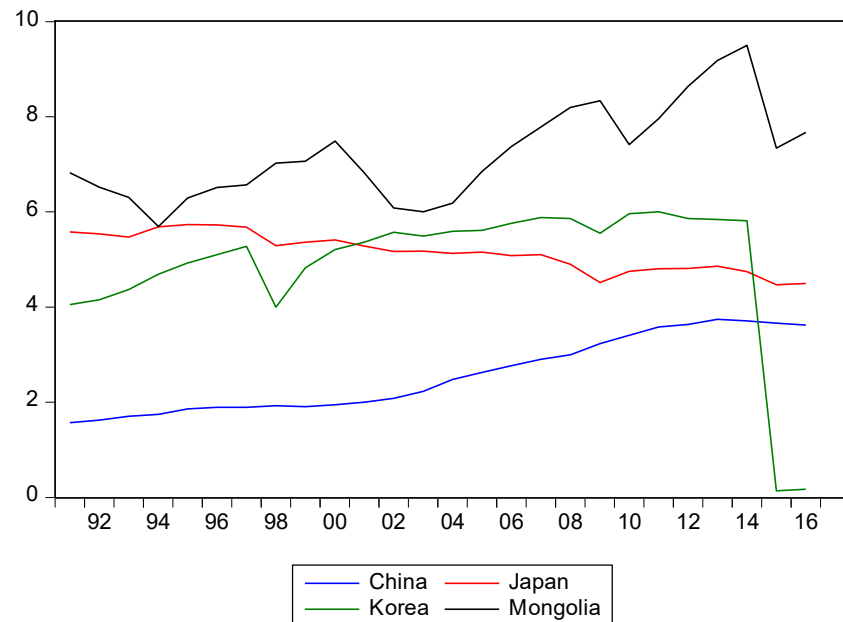


**Figure 3.2: Ecological footprint per capita consumption by Central Asia**  
Source: GFN (2019)

In case of Central Asia (Figure 3.2), Kazakhstan embraces with the highest EF followed by Turkmenistan, Uzbekistan and Azerbaijan and lowest was accounted in Tajikistan. In driving the overall EF on a regional level.



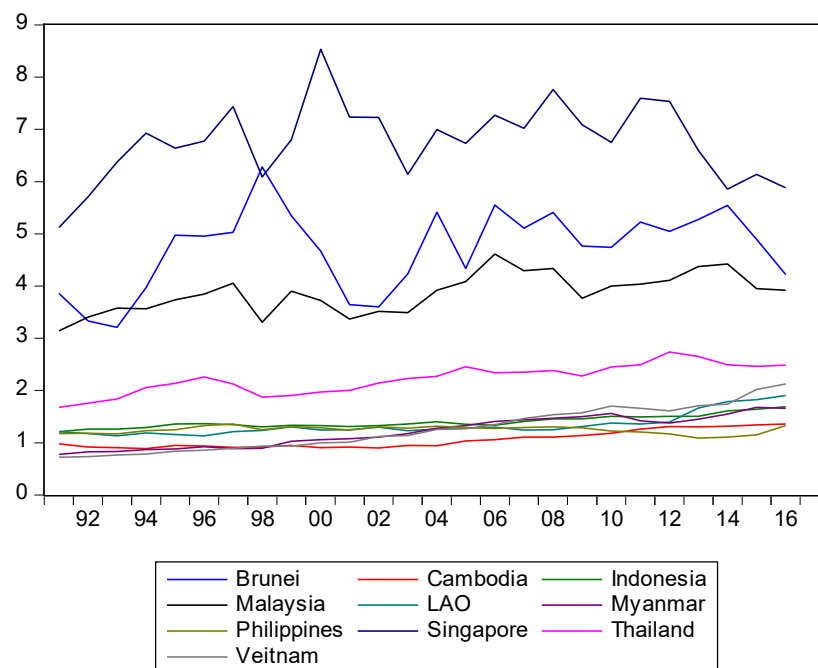
**Figure 3.3 Ecological footprint per capita consumption by South Asia**  
Source: GFN (2019)



**Figure 3.4: Ecological footprint per capita consumption by East Asia**  
Source: GFN (2019)

Per capita EF in South Asia (Figure 3.3) shows little variation and concentrated around 1 gha per person except Bhutan. It has highest EF of 4.49 gha per person, followed by Sri Lanka and India for the year 2016. Demographic transition, energy- intensive production, and industrialization cause huge GHGs emission and greater requirement of built-up land which increase EF of South Asian countries (Galli et al., 2012; Niccolucci et al., 2012). Though Bangladesh happens to be the smallest territory in South Asia, its usage of built-up land is rapidly increasing.

In the early 2000s, China's total EF has surpassed that of the US and experience drastically increase over the last 15 years. China happens to be the world's largest population, in recent years their population has stabilized and showed declining trend. China has the largest share in world's EF, but in terms of per capita, it has less than the world average (Global Footprint Network (GFN), 2019). Moreover, the scenario of EF per person in East Asian region (Figure. 3.4) is highest in Mongolia (9.49 gha) followed by Korea (5.81 gha) and Japan (4.74 gha). Carbon footprints were one of the major contributors in EF in Japan. In the late 1990s carbon footprint increased 13 times such that 65 per cent of total EF consumption was caused by carbon footprint (Japan Ecological Footprint (JEF), 2019).



**Figure 3.5: Ecological footprint per capita consumption by Southeast Asia**

Source: GFN (2019)



Lastly, Figure. 3.5 shows the EF consumption by Southeast Asian countries. It can be observed from the figure that Singapore holds the largest EF followed by Brunei, Malaysia, Thailand and other Southeast Asian regions. In the recent report from World Wildlife Fund (2018) it was observed that use of natural resources and the population has led to the environmental damages in Singapore. Furthermore, Vietnam, Myanmar, Indonesia and Cambodia have almost same level of EF consumption during 2016.

### **3.2: Literature review**

The pioneering work of Grossman and Krueger (1991) advocated that the relationship between economic growth and environmental pollution follows an inverted U-shape relationship. It states that in the early stage of country's growth, environmental pollution deepens, after reaching at certain threshold level, environmental pollution starts declining. It is a preference mechanism and priority setting between economic growth and environmental pollution for developing countries. Advocate of EKC hypothesis argued for focus on economic growth first then preferences will shift to clean environment. In short, there exists a non-linear association between growth-emissions.

Based on the EKC argument, extensive research has been done to empirically test the income-emissions. Simple classification and review of all literature is out of scope of this study. Various studies has been conducted and differ in terms of methods, sample countries, study periods, variables and results. For the simplicity, literature has been reviewed into strand. The first strand includes studies based on CO<sub>2</sub> emissions as an indicator of environmental pollution. Since international negotiation targeted the CO<sub>2</sub> emissions to fight the climate change. Extensive studies used CO<sub>2</sub> emissions (total or per capita) and test the EKC hypothesis using different econometric methods (Ulucak and Bilgili, 2018). Along with economic growth as a key variable in empirical testing of EKC, consumption of energy, financial development, urbanization, trade openness are identified as the determinants of environmental degradation (Shahbaz et al., 2013b).

Sarkodie and Ozturk (2020) investigate the relationship between energy efficiency and energy consumption in Kenya by using Autoregressive distributed lag (ARDL) approach. The empirical finding exposed that the use of energy increases CO<sub>2</sub> emissions. Moreover, inverted

U-shaped EKC is found between economic growth and carbon emissions. Shahbaz et al. (2016) explored the role of globalization on selected African countries. The empirical findings proves the development of globalization reduces CO<sub>2</sub> emissions. Their study also supported the presence of EKC in six countries. Ahmed et al. (2019) studied the impact of trade openness on environmental degradation for selected eight developing countries. They revealed that energy consumption, export and country's growth remained significant factor for emissions and found an inverted U-shaped association between economic growth and environmental pollution. Arrow et al. (1995) found people tend to spend more proportionately as economic growth happens. Recently several studies highlighted role of trade and globalization in increasing the demand of goods and services. Shahbaz et al. (2015a) finds that impact of trade openness on CO<sub>2</sub> emissions depends on its economic and financial development. Antweiler et al. (2001) reveals that trade openness expected to improve CO<sub>2</sub> emissions. In recent study by Salahuddin et al. (2016) stated that increase in financial growth across different regions in Gulf cooperation council may cause higher carbon dioxide (CO<sub>2</sub>) emissions. Pao and Tsai (2011a) showed that massive use of energy enhance CO<sub>2</sub> emissions. Shahbaz et al. (2016) reported that globalization and consumption of energy are the important determinants of emissions in China. Kalayci and Hayaloglu (2018) reach the same conclusion for North American free trade agreement countries. Moreover, Xu et al. (2018) applies ARDL approach and causality test to study the dynamic association between financial development, globalization and CO<sub>2</sub> emissions using time series data for the period 1971–2016 in Saudi Arabia. They find globalization to be insignificant on environment quality. Similar results were also pointed out by Haseeb et al. (2018) for BRICS countries. A recent study by Zhang (2019) found that there is no evidence of the EKC in Central Asia when he used the Pedroni cointegration and the Dumitrescu-Huilingranger causality test. His results further reveals that urbanization plays an important role in explaining carbon emissions.

The second group of studies used EF as an indicator of environmental quality, and tested the EKC hypothesis using real GDP, square of real GDP. This group further extended to include trade openness, financial development, energy consumption, globalization and urbanization as additional independent variables. In considering the validity of EKC, Mrabet and Alsamara (2017) and Fakher (2019) confirmed the presence of EKC. In contrast Bagliani et al. (2008) and Pablo-Romero and Sanchez-Braza (2017) did not support the EKC when using EF. Galli et al. (2012) found that “global EF increased in high income nations while in low and middle income countries it declined or remained constant”. Furthermore, Al-Mulali et al. (2015)

analysed the impact of real GDP, financial development and renewable energy consumption on EF for Caribbean and Latin American countries and did not find any evidence in support of EKC in low income nations while they revealed inverted U-shaped relationship in upper middle and high income countries. The findings of Moran et al. (2008) revealed a positive relationship between economic growth and EF. Al-Mulali et al. (2015b) claimed that in the panel of 93 countries, openness in trade increases EF while financial development reduces it. Sabir and Gorus (2019) used pooled cross country data for South Asian countries over the period 1975–2017 to investigate the effect of globalization and technological changes on the emissions. Their empirical findings show existence of EKC and positive effect of globalization on EF. Charfeddine and Mrabet (2017) examined the impact of economic growth and urbanization on EF and finds urbanization to be statistically significant and negative effect in the panel of 15 Middle East and North Africa countries.

It is surprising that although substantial proportion of Asian countries is accountable for worlds environmental emissions, none of the accessible researcher have investigated environment Kuznets relationship by utilizing EF indicator in the case of Asian sub regions panel. Thus, this chapter examines the existence of EKC hypothesis by employing EF indicator. Secondly, the study examines the environmental effect of economic growth on EF indicator (environmental degradation indicator) in determining the shape of EKC and devise appropriate policy implication. Third, to sustain empirical results and reach out reliable policy conclusion, it is quite imperative to apply a robust method to overcome with this issue of heterogonous panel analysis. For this purpose, the Lagrange multiplier (LM) proposed by Breusch and Pagan (1980) is employed to identify the presence of cross sectional dependence. Fourth, second generation long run estimates Pesaran et al. (1999) Pooled mean group (PMG), Stock and Watson (1993) dynamic ordinary least square (DOLS) is applied to examine the long run coefficients and to ensure the accuracy and robustness. Finally, Asian countries are potential contributor to environment degradation globally and at the same time, demand for energy in these countries is high. As literature is scant on examine the Asian sub region countries, hence this chapter will adds to the debate on the EKC. Therefore, it is essential to analyse the validity of the EKC hypothesis in these sub regions to fill the research gap and to make predictable policy implication. Furthermore, control variables such as energy consumption, urbanization and globalization is used as additional variables as to observe their effects on environment.

The rest of the chapter is organized as follows: Section 3.3 discusses data and model specification used in this chapter. Section 3.4 reports empirical methodology. Results and discussion is presented in section 3.5. Finally section 3.6 concludes the chapter.

### **3.3: Data and model specification**

The study employed annual data spanning from 1991 to 2017 for the 37 Asian countries. Period of analysis is taken based on the availability of data. To analysed the validity of EKC hypothesis and measure the comparative performance of globalization, urbanization and energy consumption on environmental degradation, this chapter classified the Asian countries into five sub-regions; (i) West Asia (Israel, Jordan, Oman, Turkey, Lebanon, United Arab Emirates (UAE), Saudi Arabia, Iraq, Cyprus and Yemen), (ii) Central Asia (Kazakhstan, Armenia, Azerbaijan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan), (iii) South Asia (India, Bangladesh, Nepal, Sri Lanka, Pakistan and Bhutan), (iv) East Asia (China, Japan, Korea and Mongolia), (v) Southeast Asia (Indonesia, Malaysia, Singapore, Myanmar, Brunei, Philippines, Thailand, Vietnam, Cambodia and Lao). Then, using per capita EF as an indicator for environmental pollution, we establish a Kuznets curve model.

Concerning the driving factors of the above mentioned environmental indicators, this study have taken major socio-economic and geophysical drivers for EF indicator. This will allow to do a comparative analysis.

In order to obtain a better understanding of driving factors, the study follows the similar literature that analyse the drivers of such indicators and following variables have been then used in this chapter.

**Economic Growth:** Since main motives is to analyse EKC, we have added economic growth and square of economic growth as main variable. It can be seen as affluence variable that represent income level and economic activities in the economy. It represent the production level of an economy and an increase in the output will demand more resources and increase EF. While overtime with increase in income, people will demand clean environment and efficient use the ecological resources which reduced EF.

**Urbanization:** During the economic development, rural–urban migration happens for occupations and succeeding urban growth. The stretch of urban and periphery will grow along with construction work, expansion of supply, transport and other infrastructures for connecting with urban centres. Hence, expansion of economic activities resulted in higher resource

demand (Liddle and Lung, 2010). However, Urbanization may provide economies of scale and promote resources efficiency and enable to minimize environmental impact (Weisz and Steinberger, 2010). The ecological modernization theory advocated that the modernity of civil society leads to emergence of ecologically rational institutions, policies, and technologies that reduces the environmental degradation. Urbanization may reduce the EF in urban areas through better management and efficient use of space, transportation and resources. It is taken as the percentage of a country's population living in urban areas.

**Energy Consumption:** It is considered as one of the key factor for escalating environmental damage. Major part of energy demand is fulfilled by fossil-fuel which responsible for major growth in emission. It is used in the literature as important determinant of environmental degradation. Particularly emission of major pollutants such as CO<sub>2</sub> and SO<sub>2</sub> are highly correlated with energy consumption. Several studies consider it as an additional variable in the basic EKC hypothesis. It connect environmental quality with economic growth. Recent studies have established the link between energy consumption and environmental degradation.

**Globalization:** Globalization connect economic growth through enhancing international trade and investment. Hence it has been seen as key element to development of a country. Globalization promoted through social, political and economic means. However its impact on environmental quality is less known, it may have favourable and unfavourable effects. It reduce cross-border restrictions on trade, investment and labour movement. It can enhance technological capacity through foreign direct investment (FDI), competition and technologies transfer. Therefore it provides resource efficiency and better management of environmental resources. It is known as the technique effect of globalization. On the contrary, globalization may deepen environmental degradation through enhancing income and economic activities. This is called as the scale effect channel. Finally, the composition effect of globalization starts when an economy start to shift from farming to manufacturing and, finally, to the services sector. In this manner, production methods might be modified as the economy evolves from the manufacturing to the services sector. Depends upon the magnitude of different effect, the impact of globalization on EF will depict. The log linear quadratic multivariate function is presented as follows:

$$\ln EF_{it} = \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{it}^2 + \beta_3 \ln EC_{it} + \beta_4 \ln URB_{it} + \beta_5 \ln G_{it} + \mu_{it} \quad (3.1)$$

Where  $i$  represent the cross-sectional and  $t$  is the time dimension in panel estimation (1991-2017). The  $\beta_1, \dots, \beta_5$  indicate the long run elasticity with respect to EF. The variables<sup>9</sup> name, their description, date source and the unit of measurement is reported in Table 3.1.

**Table 3.1 Variable Description**

| Variables              | Symbol | Description                                                                                                                   | Units                           | Source |
|------------------------|--------|-------------------------------------------------------------------------------------------------------------------------------|---------------------------------|--------|
| Ecological Footprint   | lnEF   | Sum of crop land, grazing land, forest land, fishing, infrastructure and carbon                                               | Million metric tons (MMT)       | GFN    |
| Gross domestic product | lnY    | Gross domestic product per capita                                                                                             | Constant US dollar 2010         | WDI    |
| Energy consumption     | lnEC   | Energy use per capita                                                                                                         | kg of oil equivalent per capita | WDI    |
| Globalization index    | lnG    | measured by (Dreher, 2006) as KOF index of globalization consist of mainly three parameters ( economic, political and social) | KOF index                       | SEI    |
| Urbanization rate      | lnURB  | Urbanization rate (urban population/total population)                                                                         | as per cent of total            | WDI    |

*GFN* global footprint network, *WDI* world development indicator, *SEI* swiss economics institution.

### 3.4: Empirical methodology

Because this chapter attempts to analyse the EKC hypothesis, this analysis included the square of economic growth. To this end, if the slope coefficient for the economic growth (square of economic growth) is positively ( $\beta_{1i} > 0$ ) and negatively ( $\beta_{2i} < 0$ ) significant, “an inverted U-shaped” association between economic growth and the EF will result, which represents EKC hypothesis. Thirty seven Asian countries will be analysed and categories by Asian sub panels as West Asia-, Central Asia-, South Asia-, East Asia- and Southeast Asian countries.

Since the period of study is long enough, this study have applied time series technique of unit-root (stationarity), cointegration, and long- and short-run results estimation. To assess the stationarity of the variables, a battery of unit root tests are performed. After checking the presence of unit-root that variables are of first-difference stationary, the Pedroni (1999, 2004) and Kao (1999) panel cointegration test is then used to check the long-run association among the variables. Once it is confirmed that the variables are cointegrated, the PMG developed by Pesaran and Smith (1995), and Pesaran et al. (1999) is used to estimate the long run association

<sup>9</sup> the variables are converted into natural log form to interpret the estimated coefficients (Paramati et al., 2017)

among the analysed variables. In addition, to check for the accuracy and robustness of the obtained analysis from the panel PMG estimates, the panel DOLS technique developed by Stock and Watson (1993) is employed. The former is basically an augmentation of ARDL model, and take care of heterogeneity which restrict long run coefficients.<sup>10</sup> It allow short run coefficients to vary across countries together with error variances and intercepts. There is also an adjustment mechanism toward long-run equilibrium from any short run deviation known as error correction term (ECT). Hence, the possible endogeneity can also be removed by applying suitable form of lags of different variables in the ECT. The specification of error correction model of PMG is given by;

$$\Delta m_{it} = \alpha_i (m_{i,t-1} - \varphi'_i n_{i,t-1}) + \sum_{j=0}^{y-1} \rho_{ij}^* \Delta m_{i,t-1} + \sum_{j=0}^{x-1} \delta_{ij}^* \Delta n_{i,t-j} + \varphi_i + \mu_{it} \quad (3.2)$$

Here,  $m$  portrays the EF (dependent variable),  $(m_{i,t-1} - \varphi'_i n_{i,t-1})$  represents the long run deviation,  $\alpha_i$  is speed of adjustment associated with error correcting terms. There is an evidence of no cointegration if  $\alpha_i = 0$  which assumed to be negative and statistically significant. Vector  $\delta$  and vector  $\varphi_i$  constitute the short run and long run coefficients<sup>11</sup> respectively.  $\mu_{it}$  is the residual term and finally  $\varphi_i$  is country specific effect unobserved time invariant.

Apart from PMG, this study have applied DOLS which is quite productive in eliminating the autocorrelation issue in the residual terms and endogeneity problem in the regressors (Bhattacharya et al., 2016). Moreover, by employing parametric approach, DOLS method eliminates the problem of explanatory variables and its lags.

Before applying panel data technique, first, this study have checked the presence of cross-sectional dependence (CSD) in the Asian sub-region countries. To test CSD, LM technique developed by Breusch and Pagan (1980) has been applied<sup>12</sup>. According to the results given in Table 3.2, the null of cross-sectional independence is rejected in all the countries of all the Asian groups at 1 per cent significance level. Hence it confirms the presence of CSD.

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<sup>10</sup> In literature, presently there are 3 dynamic approaches, the first is dynamic fixed effects in which only error variances and intercept are allowed to vary and it completely avoids the heterogeneity across cross sections. The second is MG (Mean Group) given by Pesaran and Smith (1995) which allows short-long run coefficients, error variances and intercepts to vary. And, finally Pesaran and Smith (1995) PMG approach where short run, error variances and intercepts are allowed to vary across groups.

<sup>11</sup> dependent variable w.r.t. each regressors shown by  $n_{i,t-1}$

<sup>12</sup> in case of panels with  $T > N$ , this test performs better

**Table 3.2: Cross sectional dependence test**

| Asian Panel  |          |       | South Asia     |         |       |
|--------------|----------|-------|----------------|---------|-------|
| Variables    | BP-LM    | Prob  | Variables      | BP-LM   | Prob  |
| lnEF         | 4853.23  | 0.00* | lnEF           | 96.42   | 0.00* |
| lnY          | 11607.14 | 0.00* | lnY            | 393.98  | 0.00* |
| lnY2         | 11657.66 | 0.00* | lnY2           | 393.59  | 0.00* |
| lnEC         | 5925.10  | 0.00* | lnEC           | 199.10  | 0.00* |
| lnG          | 14411.21 | 0.00* | lnGI           | 342.65  | 0.00* |
| lnURB        | 12625.36 | 0.00* | lnUR           | 361.60  | 0.00* |
| West Asia    |          |       | East Asia      |         |       |
| Variables    | BP-LM    | Prob  | Variables      | BP-LM   | Prob  |
| lnEF         | 294.85   | 0.00* | lnEF           | 63.69   | 0.00* |
| lnY          | 443.98   | 0.00* | lnY            | 146.79  | 0.00* |
| lnY2         | 443.69   | 0.00* | lnY2           | 146.85  | 0.00* |
| lnEC         | 275.54   | 0.00* | lnEC           | 76.53   | 0.00* |
| lnG          | 815.51   | 0.00* | lnGI           | 155.19  | 0.00* |
| lnURB        | 877.42   | 0.00* | lnUR           | 136.12  | 0.00* |
| Central Asia |          |       | Southeast Asia |         |       |
| Variables    | BP-LM    | Prob  | Variables      | BP-LM   | Prob  |
| lnEF         | 145.00   | 0.00* | lnEF           | 387.04  | 0.00* |
| lnY          | 446.08   | 0.00* | lnY            | 1016.78 | 0.00* |
| lnY2         | 445.26   | 0.00* | lnY2           | 1026.20 | 0.00* |
| lnEC         | 174.89   | 0.00* | lnEC           | 453.49  | 0.00* |
| lnG          | 526.20   | 0.00* | lnGI           | 1011.58 | 0.00* |
| lnURB        | 307.02   | 0.00* | lnUR           | 792.11  | 0.00* |

Note: \*denote rejection of null of cross sectional independence at 1 per cent significance level. *Prob.* Probability value.

Source: Author's calculation (2019).

### 3.5: Results and Discussion

#### 3.5.1: Unit root analysis

Testing the stationarity of the data is an important step in an empirical analysis. If its mean and autocovariances do not depend on dimension, a variable is said to be stationary. Because this empirical chapter uses a panel data technique and presence of CSD, the stationary properties of all the variables have been tested by three different panel unit root test; namely, IPS test developed by Im et al. (2003), nonparametric Fisher type ADF test and Phillips-Peron (PP) test developed by Maddala and Wu (1999). In the context of panel unit root analysis these tests have also been used by previous studies (Charfeddine and Mrabet, 2017). These tests assumes individual unit root and allows for panel heterogeneity for all the panel units in the process of autoregressive coefficients which may differ across countries. The IPS, ADF and PP merge



individual series to derive panel unit root test results and work under the null of non-stationary (unit root) as against an alternate of stationary (no unit root)

The results from the panel unit root tests are reported in panel I, II and III, of Table 3.3, namely, the IPS, ADF and PP unit root tests. It can be observed from the Table 3.3 that majority of the variables contain unit root but after first-difference they become stationary. This implies that there is a mixture some are stationary at level and mostly are at first difference. Hence the next step in the analysis is to examine the long-run association among the variables.

**Table 3.3: Panel unit root results**

| Panel: I Im, Pesaran and Shin (IPS) | Variables        | Level     |                   | First difference |                   |
|-------------------------------------|------------------|-----------|-------------------|------------------|-------------------|
|                                     |                  | intercept | Intercept & trend | intercept        | Intercept & trend |
| Asian panel                         | lnEF             | 1.45      | (2.42*)           | -21.88*          | -18.98*           |
|                                     | lnY              | 8.97      | -0.78             | -14.36*          | -12.11*           |
|                                     | lnY <sup>2</sup> | 10.59     | -2.03**           | -14.03*          | -12.03*           |
|                                     | lnEC             | 0.45      | -3.11*            | -21.53*          | -20.60*           |
|                                     | lnG              | -4.60*    | -0.01             | -21.31*          | -21.35*           |
|                                     | lnURB            | 0.56      | -1.83**           | -7.69*           | -11.82*           |
| West Asian countries                | lnEF             | 2.19      | 1.21              | -12.53*          | -11.48*           |
|                                     | lnY              | 0.60      | 3.08              | -6.00*           | -4.62*            |
|                                     | lnY <sup>2</sup> | 0.70      | 3.07              | -5.97*           | -4.62*            |
|                                     | lnEC             | 0.48      | 1.49              | -13.89*          | -14.21*           |
|                                     | lnG              | -1.07     | 1.86              | -10.50*          | -11.99*           |
|                                     | lnURB            | -1.64***  | -0.79             | -19.08*          | -21.82*           |
| Central Asian countries             | lnEF             | -2.87*    | -3.96*            | -7.60*           | -5.94*            |
|                                     | lnY              | 2.56      | -4.71*            | -7.34*           | -4.42*            |
|                                     | lnY <sup>2</sup> | 2.82      | -7.09*            | -7.20*           | -4.40*            |
|                                     | lnEC             | -4.13*    | -7.20*            | -8.60*           | -6.68*            |
|                                     | lnG              | -3.79*    | -0.46             | -7.62*           | -7.42*            |
|                                     | lnURB            | -0.25     | -2.52*            | 0.43             | -3.51*            |
| South Asian countries               | lnEF             | 2.04      | 0.06              | -9.92*           | -8.77*            |
|                                     | lnY              | 9.76      | 2.28              | -6.91*           | -7.45*            |
|                                     | lnY <sup>2</sup> | 11.07     | 2.99              | -6.38*           | -7.45*            |
|                                     | lnEC             | 3.01      | 2.23              | -9.28*           | -9.42*            |
|                                     | lnG              | 0.35      | -0.78             | -9.94*           | -9.44*            |
|                                     | lnURB            | 1.63      | -1.36***          | .52332           | -12.08*           |
| East Asian countries                | lnEF             | 1.12      | -1.89             | -5.44*           | -4.39*            |
|                                     | lnY              | 1.33      | -0.61             | -5.36*           | -3.77*            |
|                                     | lnY <sup>2</sup> | 2.04      | -1.40***          | -5.33*           | -3.70*            |
|                                     | lnEC             | 1.84      | -1.43***          | -5.49*           | -5.40*            |
|                                     | lnG              | -2.84*    | -0.31             | -7.17*           | -7.42*            |
|                                     | lnURB            | -0.62     | -0.48             | -3.46*           | -2.02**           |

|                           |                  |           |                   |                  |                   |
|---------------------------|------------------|-----------|-------------------|------------------|-------------------|
| Southeast Asian countries | lnEF             | 0.74      | -1.30***          | -12.12*          | -10.47*           |
|                           | lnY              | 6.25      | -1.83**           | -6.75*           | -6.88*            |
|                           | lnY <sup>2</sup> | 7.61      | -2.25**           | -6.68*           | -6.81*            |
|                           | lnEC             | 0.35      | -2.25*            | -9.72*           | -9.11*            |
|                           | lnG              | -3.03*    | -0.69             | -11.88*          | -10.86*           |
|                           | lnURB            | 0.80      | 0.48              | -7.00*           | -5.55*            |
|                           |                  |           |                   |                  |                   |
| Panel II: Fisher type ADF | Variables        | Level     |                   | First difference |                   |
|                           |                  | intercept | Intercept & trend | intercept        | Intercept & trend |
| Asian panel               | lnEF             | 94.33***  | 126.20*           | 529.06*          | 429.80*           |
|                           | lnY              | 33.69     | 118.06*           | 363.41*          | 298.57*           |
|                           | lnY <sup>2</sup> | 29.90     | 153.48*           | 356.22           | 294.71*           |
|                           | lnEC             | 119.29*   | 144.48*           | 514.03*          | 486.56*           |
|                           | lnG              | 155.78*   | 89.04             | 518.87*          | 474.28            |
|                           | lnURB            | 328.91*   | 124.69*           | 89.27***         | 368.92*           |
| West Asian countries      | lnEF             | 13.52     | 23.85             | 158.00*          | 139.36*           |
|                           | lnY              | 15.06     | 16.77             | 94.85*           | 71.25*            |
|                           | lnY <sup>2</sup> | 14.34     | 16.19             | 93.79*           | 70.35*            |
|                           | lnEC             | 23.47     | 14.05             | 168.30*          | 186.81*           |
|                           | lnG              | 25.45     | 22.50             | 139.44*          | 137.78*           |
|                           | lnURB            | 276.12*   | 34.33**           | 47.60*           | 291.51*           |
| Central Asian countries   | lnEF             | 37.02*    | 45.05*            | 78.87*           | 57.80*            |
|                           | lnY              | 10.68     | 51.40*            | 74.94*           | 49.84*            |
|                           | lnY <sup>2</sup> | 9.83      | 78.08*            | 74.31*           | 47.84*            |
|                           | lnEC             | 51.92*    | 73.28*            | 88.49*           | 68.16*            |
|                           | lnG              | 39.52*    | 15.02             | 78.41*           | 72.89*            |
|                           | lnURB            | 18.12     | 34.95*            | 19.35            | 39.96*            |
| South Asian countries     | lnEF             | 10.94     | 9.34              | 96.53*           | 77.83*            |
|                           | lnY              | 0.29      | 5.82              | 67.33*           | 65.71*            |
|                           | lnY <sup>2</sup> | 0.20      | 4.34              | 62.47*           | 65.76*            |
|                           | lnEC             | 10.39     | 2.66              | 89.77*           | 83.39*            |
|                           | lnG              | 15.50     | 17.80             | 96.46*           | 84.95*            |
|                           | lnURB            | 8.61      | 18.78***          | 5.58             | 54.55*            |
| East Asian countries      | lnEF             | 2.90      | 17.75             | 43.42*           | 33.09*            |
|                           | lnY              | 4.41      | 9.08              | 42.72*           | 29.57*            |
|                           | lnY <sup>2</sup> | 3.46      | 14.00***          | 42.68*           | 29.33*            |
|                           | lnEC             | 7.82      | 13.56***          | 42.41*           | 39.20*            |
|                           | lnG              | 25.09*    | 8.64              | 56.33*           | 53.78*            |
|                           | lnURB            | 8.30      | 15.37***          | 25.70*           | 23.99*            |
| Southeast Asian countries | lnEF             | 29.93***  | 30.20***          | 152.22*          | 121.70*           |
|                           | lnY              | 3.22      | 34.97**           | 83.55*           | 82.19*            |
|                           | lnY <sup>2</sup> | 2.05      | 40.85*            | 82.95*           | 81.41*            |
|                           | lnEC             | 25.67     | 40.92**           | 125.06*          | 108.98*           |

|                            |                  |           |                   |                  |                   |
|----------------------------|------------------|-----------|-------------------|------------------|-------------------|
|                            | lnG              | 50.19*    | 25.07             | 148.20*          | 124.87            |
|                            | lnURB            | 22.42     | 23.97             | 86.26*           | 63.94*            |
|                            |                  |           |                   |                  |                   |
| Panel III: Phillips-Perron | Variables        | Level     |                   | First difference |                   |
|                            |                  | intercept | Intercept & trend | intercept        | Intercept & trend |
| Asian panel                | lnEF             | 84.74     | 118.00*           | 560.77*          | 844.05*           |
|                            | lnY              | 61.19     | 163.71*           | 386.90*          | 419.39*           |
|                            | lnY <sup>2</sup> | 53.49     | 178.14*           | 375.48           | 431.70*           |
|                            | lnEC             | 139.77*   | 313.28*           | 595.25*          | 881.53*           |
|                            | lnG              | 222.40    | 88.02             | 545.75*          | 933.69            |
|                            | lnURB            | 192.09*   | 587.64*           | 87.68            | 302.79            |
| West Asian countries       | lnEF             | 14.69     | 22.52             | 167.28*          | 223.21            |
|                            | lnY              | 18.11     | 11.35             | 100.05*          | 80.78*            |
|                            | lnY <sup>2</sup> | 17.11     | 10.75             | 99.50*           | 80.29*            |
|                            | lnEC             | 24.13     | 17.68             | 182.44*          | 190.24*           |
|                            | lnG              | 28.53     | 26.27             | 150.97*          | 185.04*           |
|                            | lnURB            | 15.80     | 294.42*           | 41.55*           | 278.54*           |
| Central Asian countries    | lnEF             | 33.23*    | 56.89*            | 87.44*           | 63.20*            |
|                            | lnY              | 3.42      | 109.01*           | 73.36*           | 54.87*            |
|                            | lnY <sup>2</sup> | 3.45      | 118.16*           | 74.89*           | 54.47*            |
|                            | lnEC             | 57.92*    | 235.14*           | 104.93*          | 335.24*           |
|                            | lnG              | 56.59*    | 13.14             | 80.10*           | 77.23*            |
|                            | lnURB            | 49.47*    | 273.77*           | 28.45**          | 9.30              |
| South Asian countries      | lnEF             | 11.77     | 9.28              | 97.12*           | 134.75*           |
|                            | lnY              | 0.27      | 4.14              | 73.22*           | 103.22*           |
|                            | lnY <sup>2</sup> | 0.21      | 2.51              | 63.03*           | 102.24*           |
|                            | lnEC             | 10.86     | 2.37              | 90.20*           | 98.59*            |
|                            | lnG              | 20.36***  | 16.99             | 97.06*           | 336.39*           |
|                            | lnURB            | 64.27*    | 11.83             | 94.52*           | 33.18**           |
| East Asian countries       | lnEF             | 2.44      | 8.11              | 53.80*           | 46.61*            |
|                            | lnY              | 34.09*    | 10.63             | 44.76*           | 99.05*            |
|                            | lnY <sup>2</sup> | 30.25*    | 9.75              | 44.65*           | 114.29*           |
|                            | lnEC             | 26.25*    | 35.60*            | 46.69*           | 102.41*           |
|                            | lnG              | 71.38*    | 8.45              | 65.45*           | 180.70*           |
|                            | lnURB            | 33.61*    | 6.70              | 25.18*           | 1.62              |
| Southeast Asian countries  | lnEF             | 22.58     | 21.18             | 155.10*          | 376.26*           |
|                            | lnY              | 5.28      | 28.56***          | 95.49*           | 81.45*            |
|                            | lnY <sup>2</sup> | 2.46      | 36.94**           | 93.39*           | 80.39*            |
|                            | lnEC             | 20.59     | 22.47             | 170.98*          | 155.04*           |
|                            | lnG              | 45.52*    | 23.15             | 152.15*          | 154.31*           |
|                            | lnURB            | 89.13*    | 6.13              | 86.31*           | 63.31*            |

Note: \*, \*\* and \*\*\* Indicate the rejection of null of non-stationary and statistical significance at 1, 5 and 10 per cent level respectively.

Source: Author's calculation (2019)

### 3.5.2: Cointegration analysis

The results from two different panel cointegration test are reported in panel a & b of Table 3.4. First is residual-based heterogeneous Pedroni (1999, 2004) test with various individual effects for CSD is estimated to serve the objective. It has seven different test statistics to examine the null of no cointegration with first three are non-parametric approach (panel v statistics, panel rho statistics, and panel PP statistics) while panel ADF statistics is a parametric approach, these tests are known as within dimension statistics. The other individual AR coefficients are group rho statistics, group PP statistics (nonparametric) and group ADF statistics (parametric) are known as between dimension approach as group mean statistics. The study also applied Kao (1999) cointegration test given by Maddala and Wu (1999) for robustness purpose.

**Table 3.4: Panel cointegration test**

| a) Pedroni test $EF = f(Y, Y^2, EC, G, URB)$ |             |       |           |        |              |        |            |       |           |         |                |       |
|----------------------------------------------|-------------|-------|-----------|--------|--------------|--------|------------|-------|-----------|---------|----------------|-------|
|                                              | Asian panel |       | West Asia |        | Central Asia |        | South Asia |       | East Asia |         | Southeast Asia |       |
| Common AR coefs. (within-dimension)          | Statistic   | Prob. | Statistic | Prob.  | Statistic    | Prob.  | Statistic  | Prob. | Statistic | Prob.   | Statistic      | Prob. |
| Panel v-Statistic                            | -1.64       | 0.95  | -0.89     | 0.81   | 0.62         | 0.26   | -0.12      | 0.55  | 0.46      | 0.03**  | -3.69          | 0.99  |
| Panel rho-Statistic                          | 2.29        | 0.98  | 1.99      | 0.97   | 0.10         | 0.54   | 1.31       | 0.90  | 0.51      | 0.69    | 4.41           | 1.00  |
| Panel PP-Statistic                           | -3.83       | 0.00* | -2.21     | 0.01** | -3.16        | 0.00*  | -2.35      | 0.00* | 0.33      | 0.06*** | 1.64           | 0.95  |
| Panel ADF-Statistic                          | -6.11       | 0.00* | -3.61     | 0.00*  | -2.43        | 0.00*  | -3.75      | 0.00* | -3.69     | 0.00*   | -3.33          | 0.00* |
| Group rho-Statistic                          | 4.09        | 1.00  | 2.81      | 0.99   | 1.24         | 0.89   | 2.14       | 0.98  | 1.23      | 0.89    | 4.35           | 1.00  |
| Group PP-Statistic                           | -4.20       | 0.00* | -5.53     | 0.00*  | -1.81        | 0.03** | -2.73      | 0.00* | 0.56      | 0.71    | -4.55          | 0.00* |
| Group ADF-Statistic                          | -5.91       | 0.00* | -4.50     | 0.00*  | -3.48        | 0.00*  | -3.94      | 0.00* | -4.75     | 0.00*   | -3.00          | 0.00* |
|                                              | Asian panel |       | West Asia |        | Central Asia |        | South Asia |       | East Asia |         | Southeast Asia |       |
| b) Kao test                                  | t-Value     | Prob. | t-Value   | Prob.  | t-Value      | Prob.  | t-Value    | Prob. | t-Value   | Prob.   | t-Value        | Prob. |
| ADF                                          | 0.15        | 0.00* | -3.83     | 0.00*  | -7.08        | 0.00*  | -2.47      | 0.00* | -3.28     | 0.00*   | -3.22          | 0.00* |

Note: \*, \*\* and \*\*\* Indicate the rejection of null no cointegration and is statistically significance at 1, 5 and 10 per cent level respectively. *Prob.* Probability value.

Source: Author's calculation (2019)

Table 3.4 reveals the panel cointegration results for the Asian panel-, West-, Central-, South-, East and Southeast<sup>13</sup> Asian countries. It is evident from Table 3.4 that calculated values of four out of seven tests were found to be greater than critical values hence it reject the null of no

<sup>13</sup> Pedroni cointegration test in the case of Southeast Asian countries show that out of 7 test statistics only 3 tests is rejected the null of no cointegration. Still there is evidence of cointegration in the long run; this is because these three test statistics are the mixture of parametric and non-parametric approach which is assumed to be good.

cointegration at 1, 5 and 10 per cent level of significance during the study period. Similarly the lower panel of Table 3.4 shows ADF based statistics from Kao (1999) panel cointegration test. It also rejects the null of no cointegration and hence validating the existence of cointegration among the considered variables. Thus, it can be concluded that EF, economic growth, square of economic growth, energy consumption, urbanization, and globalization are cointegrated in the long run. Now the study proceed for long- and short-run coefficient estimation and analyse the effect of considered variables on the EF.

### **3.5.3: Empirical analysis and Discussion**

Finally, the long-run elasticities of covariates on EF can be meaningfully derived as cointegration is established. For this purpose, PMG and DOLS estimator has been applied. PMG results for Asian panel and sub-panel group given in Table 3.5. In case of Asian panel countries, it show positive impact of economic growth on the EF while its square term turn to be negative. Hence it evident that after reaching certain threshold level of income, EF tends to decline as advocated by the EKC hypothesis. While in case of sub-panel, only Central and East Asia follows similar pattern. This association between economic growth and EF is consistent with the studies like Ulucak and Bilgili (2018), and Fakher (2019). On the contrary West, South and Southeast Asian panel shows that economic growth (the square of economic growth) is negative (positive) i.e  $\beta_{2i} < 0$  and  $\beta_{1i} > 0$ . Hence contrary to EKC of “inverted U shape” the results depicts a U shaped association with the EF. This findings is in line with those of Bagliani et al. (2008), Pablo-Romero and Sanchez-Braza (2017). It may be due to inefficient production system that does not take care of environmental impact. Hence at initial stage, they starts utilizing its idle capacity and lying natural resources and after that it causing environmental damage.

Coming to the other covariates, PMG results reported in Table 3.5, reveals energy consumption bear significant positive impact on EF for all different panels of countries. This positive relationship between energy consumption and EF is consistent with many studies like Ahmed et al. (2019), Charfeddine and Mrabet (2017) and Mrabet and Alsamara (2017). Demand of energy, particular fossil-fuel, is increasing in these developing countries which cause huge environmental pollution hence it require greater attention (Liu et al., 2007; Destek et al., 2018).

**Table 3.5: Pooled mean group result**

| Panel a: Long-run Estimates  |             |       |           |        |              |        |            |        |           |       |                |       |
|------------------------------|-------------|-------|-----------|--------|--------------|--------|------------|--------|-----------|-------|----------------|-------|
|                              | Asian panel |       | West Asia |        | Central Asia |        | South Asia |        | East Asia |       | Southeast Asia |       |
| Variables                    | Coeff.      | Prob. | Coeff.    | Prob.  | Coeff.       | Prob.  | Coeff.     | Prob.  | Coeff.    | Prob. | Coeff.         | Prob. |
| lnY                          | 0.75        | 0.00* | -4.14     | 0.00*  | 2.03         | 0.00*  | -0.69      | 0.00*  | 6.75      | 0.00* | -2.57          | 0.00* |
| lnY <sup>2</sup>             | -0.04       | 0.00* | 0.26      | 0.00*  | -0.10        | 0.00*  | 0.05       | 0.00*  | -0.31     | 0.00* | 0.20           | 0.00* |
| lnEC                         | 0.12        | 0.00* | 0.31      | 0.00*  | 0.96         | 0.00*  | 0.30       | 0.00*  | 0.37      | 0.00* | 0.09           | 0.00* |
| lnG                          | 0.19        | 0.00* | 0.74      | 0.00*  | 0.01         | 0.94   | 0.14       | 0.00*  | -0.98     | 0.00* | 0.26           | 0.00* |
| lnURB                        | -0.08       | 0.50  | 0.002     | 0.00*  | -0.24        | 0.00*  | -0.01      | 0.00*  | 0.002     | 0.10  | 1.17           | 0.00* |
| Panel b: Short Run Estimates |             |       |           |        |              |        |            |        |           |       |                |       |
| Error correction             | -0.27       | 0.00* | -0.76     | 0.02** | -0.27        | 0.03** | -0.70      | 0.02** | -0.58     | 0.00* | -0.59          | 0.00* |
| D(lnY)                       | -2.33       | 0.67  | 47.11     | 0.33   | -0.00        | 0.99   | -5.86      | 0.47   | -29.64    | 0.16  | -9.15          | 0.57  |
| D(lnY <sup>2</sup> )         | 0.21        | 0.47  | -2.10     | 0.40   | -0.04        | 0.87   | 0.46       | 0.44   | 1.73      | 0.15  | 0.52           | 0.49  |
| D(lnEC)                      | 0.11        | 0.64  | 0.40      | 0.02** | 0.08         | 0.52   | 0.49       | 0.00*  | -1.13     | 0.33  | 0.09           | 0.33  |
| D(lnG)                       | -0.16       | 0.31  | 0.77      | 0.43   | -0.37        | 0.01** | 0.44       | 0.44   | -2.57     | 0.39  | -0.37          | 0.43  |
| D(lnURB)                     |             |       | 3.33      | 0.29   | -0.34        | 0.16   | 0.95       | 0.55   | -0.03     | 0.70  |                |       |
| D(lnURB-1)                   |             |       | -3.20     | 0.21   |              |        | -2.37      | 0.41   | -0.13     | 0.42  |                |       |
| Obs.                         | 925         |       | 220       |        | 182          |        | 138        |        | 100       |       | 250            |       |
| Log likelihood               | 1702.67     |       | 553.35    |        | 295.89       |        | 362.78     |        | 180.07    |       | 547.98         |       |

Note: \*, \*\* and \*\*\* Indicate the statistical significance at 1, 5 and 10 per cent level respectively. *Coeff.*

Coefficient, *Prob.* Probability value.

Source: Author's calculation (2019).

In addition, it was observed that globalization on average is positive and significant hence it increases the environmental pressure across Asian countries. This association is expected as globalization can directly impact growth through increased trade, FDI and total factor productivity while indirectly it also give rise to carbon emissions with higher consumption of energy. In other words, in the developing countries globalizations give rise to pollution industries where weak environmental policy exists (Copeland and Taylor, 2004). As mentioned earlier there are different classifications of globalization (social, political and economic) it can have direct impact of pollution in which human being coexists. The studies like Shahbaz et al. (2015a) and Frankel (2003) supported that the globalization have a positive impact on EF. By taking KOF globalization Shahbaz et al. (2017) analysed the effect of globalization on EF in China and observed that globalization is good for China. The empirical finding further show

that globalization does not have significant impact on EF<sup>14</sup> in the case of Central Asian panel. This may be due to these countries unable to make appreciable and effective use of globalization by importing advanced technology in enhancing their performance to reduce EF (environmental damage). Whereas globalization is found to be negative and significant in case of East Asian panel. This finding is in conformity with studies like Charfeddine and Mrabet (2017) and Shahbaz et al. (2016). Hence contrary to overall results East Asian countries effectively use foreign investment and technical know-how to reduce its ecological burden. Finally, urbanisation overall does not having statistically significant impact on EF. While in case of sub-panel it seems to have significant impact, it has positive coefficient in case of West, East and Southeast Asian panel<sup>15</sup>, and shows in these countries urbanisation has intensify economic activities and ecological damage. Contrary to this, Central and South Asian panel have negative coefficient which depict urbanisation leads to efficiency and agglomeration effect.

**Table 3.6: Dynamic ordinary least square result**

|          | Asian panel |         | West Asia |       | Central Asia |       | South Asia |       | East Asia |         | Southeast Asia |         |
|----------|-------------|---------|-----------|-------|--------------|-------|------------|-------|-----------|---------|----------------|---------|
|          | Coeff.      | Prob.   | Coeff.    | Prob. | Coeff.       | Prob. | Coeff.     | Prob. | Coeff.    | Prob.   | Coeff.         | Prob.   |
| lnY      | 0.85        | 0.00*   | -1.09     | 0.00* | 1.05         | 0.00* | -2.79      | 0.00* | 8.62      | 0.04**  | -0.73          | 0.06*** |
| lnY2     | -0.05       | 0.00*   | 0.07      | 0.00* | -0.05        | 0.00* | 0.22       | 0.00* | -0.42     | 0.07*** | 0.07           | 0.00*   |
| lnEC     | 0.45        | 0.00*   | 0.25      | 0.00* | 0.50         | 0.00* | 0.11       | 0.00* | 1.25      | 0.00*   | 0.12           | 0.00*   |
| lnG      | 0.05        | 0.09*** | 0.55      | 0.00* | 1.09         | 0.00* | 0.47       | 0.00* | -3.06     | 0.00*   | 0.15           | 0.09*** |
| lnURB    | -0.001      | 0.20    | 0.007     | 0.00* | -0.01        | 0.00* | -0.02      | 0.00* | 0.02      | 0.44    | 0.01           | 0.05**  |
| R square | 0.91        |         | 0.90      |       | 0.99         |       | 0.99       |       | 0.57      |         | 0.99           |         |
| Obs.     | 999         |         | 270       |       | 170          |       | 146        |       | 96        |         | 270            |         |

Note: \*, \*\* and \*\*\* Indicate the statistical significance at 1, 5 and 10 per cent level respectively. *Coeff.* Coefficient, *Prob.* Probability value. Source: Author's calculation (2019)

The study also employed DOLS method to estimates long-run coefficient for the robustness purposes. The coefficient of covariates of EF reported in Table 3.6. The overall results of DOLS are similar to that of PMG, however, compared to PMG, magnitude of coefficients differ among the variables. The DOLS results for the Central-and East Asian countries indicate the validation of EKC hypothesis in both these Asian panels. Moreover, it was revealed that energy

<sup>14</sup> This study is in line with Ahmed et al. (2019) reveals globalization is not a significant determinant of the EF

<sup>15</sup> Similar results were also reported by Zhang (2019) in the case of Central Asia

use is the main sources of carbon emissions (environmental damage) hence it has positive effect on EF, Furthermore, the effect of globalization on EF is positive and negative in Central and East Asian panel respectively. Hence, the overall results of DOLS are similar to that of PMG, however, compared to PMG, there are some differences in statistical significance and magnitude of coefficients.

Asian countries are in developing stage hence it demands greater resource for infrastructure and industrial activities. It also undergoing to structural changes from agricultural to industry and moving to service sector. Hence greater effort is required for making sustainable use of ecological resources. Most countries have increasing population level which require more resources and hence undermine the damage to the environmental resources. These countries needs to properly harness the benefits from globalized world to enhance its efficiency. While process of urbanization needs to assessed and policy initiative required for achieving economies of scale and resource conservation. Both managerial and technical efforts should be putted for getting benefits from urban agglomeration of industries and societies. Further the preference of society for the importance of ecological conservation needs to be developed. Demand-based forces works for pressuring major sources of emission to install emission reduction technology. Since industries are major sources of emission, it is essential to adopt an eco-friendly operation with advanced cost-effective measures (Haider et al., 2019). It is further suggested that Asian countries should follows the developed countries for conservational of natural resources. It should adopt eco-friendly management of urban space and resources (Haider et al., 2019). While energy efficiency should be enhance with better technology and cross-border investment in efficiency enhancement project.

Moreover, Asia is well-off in mineral resources having enormous potential from powerful sunlight, tidal and wave power to sizeable hydropower and geothermal resources, wind in the centre latitudes. South Korea, in particular in a developing stage of tidal and wave resource. Japan has substantial geothermal sector whereas China has considerable solar and wind energy. Natural resource vary from country to country, still there is need to understand that consumption of renewable energy source mostly remained untapped in Asia. According to the survey conducted by World Energy Resources (2017), it was observed that globally 15.5 GW geothermal capacity were installed out of which 4.55 GW were planted in Asia. Globally, 327 GW wind were installed out of which 87.4 GW were installed in Asia. Europe were the primary



manufacturer of solar energy followed by Asia generated 11.5 GW, on the other hand, leading producer of hydropower is China which produce 61.4 (Mtoe)<sup>16</sup> annually.

### **3.6: Conclusion and policy implications**

Previous literatures have the major weakness in extensive use of CO<sub>2</sub> emissions as an indicator of environmental damage, which comprises only a small segment of entire environmental pollution. They have estimated the EKC hypothesis which may be inappropriate for deriving policies for broader set of ecological degradation. As a consequence, recent literature emphasize on a more inclusive measure on environmental damage hence utilize EF for purpose. Therefore, the main objective of this chapter is to investigate the EKC hypothesis by using EF indicator. The sample includes different panels of thirty-seven Asian countries. Asian sub-regions includes Asian panel-, West Asia-, Central Asia-, South Asia-, East Asia- and Southeast Asian countries. Panel data model has been applied for the empirical analysis particularly PMG and DOLS have been applied for long-run coefficient estimation. Mix results are found in case of sub-panels, there exhibits U-shaped relationship between economic growth and EF for West, South- and Southeast Asian countries. However, for Central- and East Asian panels, EKC hypothesis is found to be valid. One of the reasons could be the fact that for West-, South- and Southeast Asian countries, level of economic development are in the relatively growing phase. The existence of EKC depends upon the availability of better technology, renewable energy, energy saving and efficiency. Asian countries needs institutional and policy support for technology transfer from developed countries

Energy consumption leads to higher level of EF requirement, as it has significant positive impact on EF for all different panels of countries. In addition, it was observed that globalization on average drive to greater requirement and ecological resources. Hence it increases the environmental pressure across Asian countries. Whereas globalization brought significant reduction of EF in case of East Asian panel. Hence contrary to overall results East Asian countries effectively use foreign investment and technical know-how to reduce its ecological burden. Finally, urbanisation effect seems to be neutral and it does not statistically significant impact EF. In case of West, East and Southeast Asian panel, urbanisation has intensify economic activities and ecological damage. Contrary to this, Central and South Asian panel

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<sup>16</sup> Millions tons of oil equivalent.

have negative coefficient which depict urbanisation leads to efficiency and agglomeration effect

For making an inverted U-turn in the EKC practically, still much more is needed for sustainable development goals and meeting the Paris agreement especially in West-, South-, and Southeast Asian countries. This can be achieved by; (i) Increasing energy independence and energy security, (ii) reducing environmental pollution and providing access to modern energy for these countries, (iii) decreasing the demand for energy consumption in all sectors by 2030, (iv) reducing the non-renewable energy consumption, in particular oil and coal and at the same time increasing the usage of renewable energy source, (v) sufficient financial device such as incentives, grants, removal of barriers require the development to speed up the investment to boost renewable energy sector. Lastly, for achieving Paris agreement goal, removal of subsidies and carbon pricing model play an important role in retaining sustainable development objectives. In facilitating development of renewable energy, feed in tariff have already proven to be effective (REN21, 2018). Harnessing efficiency and economies effect of Urbanization and globalization will been instrumental are require policy attention.

## **Chapter 4**

### **Trade Openness and Environmental Degradation: Evidence from Income based Approach**

#### **4.1: Introduction**

Developed nations is in favour of opening economies as well as for more trade openness, as export and import has positive impact on country's growth. This changing pattern of trade has started the debate that more openness in trade may cause environmental improvement globally. Although theoretical association between quality of environmental and trade openness is not clear, but as it structure of comparative advantage changes, firms in developed countries raised the issues over dirty production of goods to less developing countries. Firms in developing nations have to face less stringent environment as compared to advance nations and are more concerned that liberalization in international trade will encourage the production of dirty industries, thus causing serious concern over environmental problems to the country (Laspidou et al., 2020).

There is a plenty of research that empirically test trade-pollution relationship; however, the results have been contradictory. For instance, Frankel and Rose (2005) analysed the relationship between environment and trade and found negative impact of trade openness on carbon dioxide (CO<sub>2</sub>) emissions, but the later studies of Managi et al. (2009) explores that the effect of trade on environment depends upon the pollutants and economic structure of the country. Their study further analysed country specific effect and finds trade detriments CO<sub>2</sub> emissions with highest concentration in Malaysia. Managi (2004) investigated the association among trade-environment nexus and showed positive effect of trade on emissions for both developed and developing nations. The recent empirical studies of Ling et al. (2015) and Sbia et al. (2014) state that trade-emissions consequences may also differ because of scale, composition and technique effects. However, the study also assessed their theoretical statement and points out several indicators that influence Asia's emissions. For example, the findings of Chandran and Tang (2013) conclude that consumption of energy significantly contribute to environmental pollution in Asia's five emerging countries, Liu et al. (2017) showed that consumption of non-renewable energy causes emissions both in short and long run, Sabir and Gorus (2019) conclude that globalization also cause environmental damage in South Asia, while Zhang (2019) conclude that urbanization showed positive impact on emissions. However, there has been mixed results in the case of Asia on the association between trade and

environment quality. Moreover, Ahmed et al. (2019) found that trade openness are highly emissions intensive and are major contributor to pollution in case of 8 developing countries of Asia, whereas Ansari et al. (2020) conclude that Asia's trade have negative correlation with environmental degradation. Although abundant empirical work has analysed the development-emission nexus in case of Asia, further empirical investigations is required on the profile of country's emissions due to involvement of various other development indicators. The simultaneous growth in institutional quality and technology on which the liberalization of trade is mainly depends on. In recent years pollution has become a serious concern in Asian countries especially in China, India and Japan are the top three Asian nations with largest amount of carbon emissions. Hence, Asian countries requires substantial investment in infrastructure development and energy resources in order to use effective use of regional resources which allows to decelerate global carbon emissions and improve the energy efficiency rate. Hence whether Asian countries has potential to achieve sustainable development economy is still remained unanswered. This chapter analysed the impact of trade effect on environmental pollution employing 'decomposed trade openness into scale effect, technique effect and composition effect'. Moreover, the energy consumption and trade openness effect is an additional control variables.

Further, recent discussion over energy and environment has been subject to continued ongoing globalization and smooth spells of trade liberalization (Ahmed, 2014), thus suggests sustainability both in terms of development-wide and energy-wide openness in trade is considered as the most important factor. Although in case of industrialized countries strong policy guidelines and sufficient literature is available, the ongoing debate requires future formulation of policy recommendation both for making strategies and abatement of environmental degradation. Doing so, this chapter attempts to investigate the effect of trade openness on the ecological footprint (EF) for the panel of high income, upper middle and lower middle income countries for thirty five Asian economies. For last many years, the state of ecosystem in Asia has been declining. Unsustainable exploitation of marine resources and extensive coastal development have resulted in the destruction of coastal habitats such as salt marshes, wetlands, seagrasses, mangroves and corals. Freshwater ecosystem have been converted for the use of agriculture and polluted with urban waste and their natural flow has been disrupted by storage of water for hydropower, domestic use, agriculture. This has led to reduce access to clean water, declining freshwater fish stocks and low agriculture productivity. The gap between the natural resource demand and the environment's ability to replenish those

resources (bio capacity deficit) in Asian countries is widening. The effect of this rising bio-capacity deficit can potentially lead to worsening climate change, overharvesting of renewable resources, widespread habitat loss, and environmental degradation. According to global footprint network, the national EF of Japan, Indonesia, India and China together contribute more than three quarters of the total EF of the Asian region. However, due to its large population, China is the largest of all the countries of Asia, in terms of national footprint consumption. Moreover, these countries rely on non-renewable energy source to meet their energy needs and are heavily dependent on import with no let expected in the near future. The demand for energy in Asian countries will continue to increase and will surpass in terms of global energy demand with rest of the world (United Nations, 2010). The greatest challenge for all the countries of Asia is to manage their natural capital<sup>17</sup> so that they maintain these services in the interest of long term growth without degrading the ecosystem services that underpin the natural environment and livelihood.

Since international trade plays an important role in country's development and provides a better indication of the growth process over time. There is a need of close examination of the relationship between environmental degradation and its influencing macroeconomic factors to design nuance trade, energy and environmental policy. The importance of trade openness can be viewed as fostering technology transfer and coordination across countries to combat climate change. Moreover, energy consumption can be viewed as increasing fossil-fuel consumption and providing inefficiency in natural resources consumption. Hence trade factor are expected to enhance environmental quality while energy consumption are expected to deteriorate environmental quality<sup>18</sup>. The objective of this chapter is to analyse the impact of trade openness on the EF. Though several panel studies have been conducted on the group of countries like Gulf cooperation council, European Union, Middle East and North Africa countries, but given the importance of EF and its widening bio-capacity in the region, we have selected the Asian countries to shed some more light on these economies. The chapter contributes to the literature

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<sup>17</sup> Natural capital such as marine, coastal, freshwater, biodiversity and forests ecosystem is important in making green economies. It is the stock of natural resources and assets that provide ecosystem services such as absorption of human waste products like CO<sub>2</sub>, pollination of crops, timber, water and food.

<sup>18</sup> There may be possibility of pollution haven hypothesis. This is because sometimes trade happens to be bad for developing countries, it is when developed nations seek to set up factories abroad, they often look for cheap labour and resources. This comes only at the cost of environmentally unsound practices.

in the following ways: (i) To author's knowledge, there is no such study that employs these variables based on the income groups of Asian countries in the same framework as examined in this paper. In the relevant literature the study is gaining interest since much concern for sustainable growth in Asia, especially these two economies India and China have experienced high economic growth without any concern relative to environmental degradation issues. Climate change in these region is one of the significant environmental challenges. These Asian countries are featured by substantial differences across their energy consumption and their level of EF and trade openness, which are further likely to worsen the association between their per capita income and the environmental degradation, threatening their significant economic development (Liu et al., 2017; Le et al., 2020). (ii) The examination of the Asian countries is of interest of policy makers and researchers since carbon emissions over the past few decades are highly rising as compared to the rest of the world according to the World Development Indicator where carbon component makes 47 per cent or more of the total EF. Moreover, per capita EF consumption (1.6 gha) in these countries, according to the global footprint network far exceeds the available bio capacity per capita (0.9 gha), leaving the bio-capacity deficit of 0.8 gha per capita. (iii) While it appears that grouping on the basis of income is an important factor, therefore to reach out the income level homogenously, we grouped Asian countries into high income, upper middle and lower middle income countries. (iv) It is pioneering effort in examining the association between the EF and trade effect by adding scale, technique, and composition effects in EF function. (v) The study employed second generation unit root test such as the cross sectionally augmented IPS (CIPS) and cross sectionally augmented Dickey-fuller (CADF) along with test which takes the issues of both heterogeneity and cross sectional dependence.

The remaining chapter is assembled as follows: "Literature Review" section supply assessment of relevant studies. The "Empirical modelling, data and methodology" part delineates the model specification, data collection, and methods applied in this chapter. The results and discussion are reported in the "Empirical Results and discussion" division, The "Panel Granger causality test" presents pairwise granger causality effect among the variables, and the "conclusion and policy implication" division summarizes article with concluding remark and some relevant policy implications.

#### **4.2: Literature review**

The prevailing literature on environment-trade nexus has contributed mixed outcome. This association among trade openness and environmental quality was first attempted by Grossman and Krueger (1991). Later, Lucas et al. (1992) investigated the relationship between trade and pollution intensity and found that with the rise in income along with trade there is reduction of pollution intensity. Grossman and Krueger (1994) examined the impact of trade openness on the quality of environment. Their empirical outcome show that openness in trade reduces environmental degradation and increases specialization in unskilled labour intensive goods in Mexico and its neighbouring countries. Porter and van der Linde (1995) argue that strict environmental regulation encourage innovations and increase efficiency. They further analysed that trade openness improves environmental quality via income growth. Economic growth has negative impact whereas trade openness has statistically insignificant on carbon emissions when Gale and Mendez (1998) examine the relationship between environmental quality, economic growth and trade openness. Dean (2002) investigated the association among trade openness, urbanization, population density, carbon emissions and found that increase in economic growth mitigates environmental pollution whereas increase in trade openness aggravate carbon emissions. Levinson and Taylor (2008) found that larger net import will take place because of strict environmental regulations.

Frankel and Rose (2005) found that for developed and developing countries trade is good for environmental quality. On contrary, Dinda and Coondoo (2006), and Mani and Wheeler (1998) supported that trade openness may have negative impact on the environment in developed countries and free trade may deteriorate environmental quality in developing countries. Kukla-Gryz (2009) mentioned that in developing countries, trade openness positively influence environmental pollution at early stage of economic development. Takeda and Matsuura (2006) examined the relationship between CO<sub>2</sub> emissions, export, and import spanning the period from 1988–2000 for East Asian countries. Their empirical results reveals that increasing dirty import from Japan, United states (US) do not harm the environmental quality, while increasing dirty export to Japan, domestic economic activity inclined to raise environmental pollution in East Asia. Using Turkish data, Halicioglu (2009) analysed the granger causal relationship among CO<sub>2</sub> emissions, energy use, growth, and trade. Their findings indicate that energy use, country's growth and openness in trade leads to environmental degradation. But, Iwata et al. (2012) noted that in Organisation for Economic Cooperation and Development (OECD), country's trade affects CO<sub>2</sub> emissions insignificantly. Managi et al. (2009) investigated the

relationship between environmental quality, economic growth, and openness in trade and found that trade openness lowers CO<sub>2</sub> emissions in OECD countries while it increase in non-OECD nations. Ahmed et al. (2019) reported that openness in trade lowers environmental quality in 8 developing countries, this is because they did not follow world trade organisation (WTO) regulations.

Moreover, Ozturk et al. (2016) probed the association among real income, urbanization, trade openness and EF for high and upper middle income nations by using generalized method of moment over the period 1988–2008 in 144 countries. Their empirical result reported that the number of examined countries have a negative relationship among them. Uddin et al. (2017) applied the dynamic ordinary least squares (DOLS) model to examine the association between trade openness and EF for 27 highest emitting countries. The outcome show that real income is detrimental to EF, but openness in trade have benefits it. Similarly, Mrabet and Alsamara (2017) studied the impact of trade openness, economic growth, energy consumption on two different environmental indicators: EF and CO<sub>2</sub> emissions by using Autoregressive distributed lag (ARDL) model in the case of Qatar. Their findings reported that trade openness is detrimental to environmental quality when they use the CO<sub>2</sub> emissions whereas it improves the environmental quality when using the EF. In the case of European Union, Destek et al. (2018) used EF and reported that trade openness have negative impact on EF, but Ulucak and Bilgili (2018) noted that trade openness degrade quality of environment in high, middle and low income countries. Recently, Destek and Sinha (2020) incorporated the role of EF in trade-pollution nexus for 24 OECD countries. Using second generation panel data methodologies they found that economic growth increases EF while openness in trade reduces it.

In case of Asian countries, researchers have listed down the various arguments regarding the effect of international trade on EF and examined its empirical evidences. For example, Liu et al. (2017) analysed the trade-emissions nexus for 42 Asian countries from 2007 to 2016 and found that trade openness have significant effect on the EF. Later studies by Ansari et al. (2020) found the statistically positive impact of trade openness on emissions in case of West Asia and statistically negative impact in Central, East, South, and Southeast Asian countries. Lee (2019) investigated the lagged effect of urbanization, industrialization and export on carbon footprint in case of Southeast Asia. He noted that only at the cost of carbon footprint, urbanization and export, economic growth is achieved. In another study, Sabir and Gorus (2019) also found that EF are positively impacted by trade openness during 1975–2017 for the South Asian countries. More recently, Le et al. (2020) examined the relationship between trade openness, energy



consumption, and economic growth on environmental degradation in 31 Asian nations over the period of 2004–2014. Their empirical finding reveals that economic growth and energy consumption increases emissions meanwhile, trade openness reduces pollution in the region. In other individual Asian countries like India, Shahbaz et al. (2015a) used globalization as a proxy for trade openness and noticed that its effect on environment is negative, similar results were also reported by Nasir and Rehman (2011), and Arouri et al. (2014) for Pakistan and Thailand respectively. Unlike, Tiwari et al. (2013)<sup>19</sup>, Shahbaz et al. (2015c) found openness in trade is beneficial for Indian economy.

#### **4.3: Theoretical framework, Method and Data**

The empirical study Antweiler et al. (2001) had disintegrated the overall effect of trade on environment into scale, composition and technique effect. The scale effect refers to the scale of economic activity. Higher economic activity leads to higher production due to free trade among the countries which is expected to increase the level of environmental pollution. The government would respond to people's demand by tightening the environmental regulation which leads to cleaner techniques of industrial production improving environmental quality. This is called the technique effect. Finally, the composition effect describes how pollution are impacted by the composition of output which in turn is decided by the comparative advantage and the degree of trade openness of the country. Our empirical model based on the empirical strategy of Ling et al. (2015) and Jena (2018). They employed per capita gross domestic product (GDP) as a proxy of scale effect, square of per capita GDP as proxy of technique effect and capital labour-ratio as a proxy of composition effect.

Theory explains scale, technique and composition effect as three major channels through which liberalization of trade can affect environment. Per capita GDP and its square term are used to capture the scale and technique effect which is consistent with the environmental Kuznets curve (EKC) literature. When income level shift from low to high levels, pollution rises and declines which takes an inverted u-shaped relationship, an important inference is to find a threshold point where nonlinear relation between income and environmental degradation exist. The third channel which shows the trade and pollution nexus are composition effect which is captured via capital-labour ratio. The production structure and their stock of factor endowment greatly differ from country to country. The country with capital-intensive industries will produce capital intensive goods and country with labour-intensive industries will produce labour-

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<sup>19</sup> Trade increases pollution level in India.

intensive goods. Therefore, capital-labour ratio that measures the relative capital intensity will produce different levels of production among different countries. Trade openness is measured by trade intensity and is calculated as the ratio of import (IM) plus export (EX) to GDP  $[(IM + EX)/GDP]$ . The existence of pollution haven depends on the type of goods exported and imported. Thus, it argues that since developed nations have rigorous environmental regulations, they relocate their pollution intensive output to developing countries where environmental regulations are flexible. The pollution haven hypothesis (PHH) received a considerable attention in developing countries. The other control variable used is energy consumption. It is considered as one of the key factor for increasing environmental pollution. As major portion of energy demand is fulfilled by non-renewable energy source which is responsible for major rise in pollution.

Environmental pollution has a multi-dimensional effect on the ecological system, hence the proxy used for environmental quality has remained mixed. Though CO<sub>2</sub> emissions are extensively analysed in the literature and remain the centre of international climate change agreements. There are some other important factors like deterioration in the quality of soil, forest, water, etc. are also notable which is facing severe ecological threats (Bartelmus, 2008). These factors are of great importance and an integral part of the ecosystem. Hence EF indicator based on the concept of carrying capacity of ecosystem is an important issue in the ecological system. Therefore EF introduced by Wackernagel and Rees (1998) is an accounting based indicator framed to capture the multi-dimensional impact on environmental degradation for which world is facing major threats. Hence recently it has been viewed as a superior measure of environmental quality and can serve as goal variable to target better environmental quality.

The objective of this chapter is to investigate the influence of international trade effect on EF through scale, technique and composition effects. In regard of Asia's export led economic development, we identify consumption of energy to play a significant role in such framework. However, via spill over effect of technological change, openness in trade not only improves energy efficiency but also liberalize increased consumption of energy in an economy. Likewise, as the economy passes transition stage, the impact of trade-growth nexus on environment, changes. In this concern, EKC hypothesis gives standard technique to study the 'inverted u-shaped' association between economic development and environmental pollution. Taking into account the trade openness as independent variable, Cole (2006), and Ling et al. (2015) advices that international trade encourages clean and efficient technology transfer and adequate policy implication towards environment and helps in better formulation of economic

policies. Jena and Grote (2008) argued that the trade-emissions nexus via consumption of energy is varied via scale, composition and technique effects. Following Tsurumi and Managi (2010), Zhang (2012), Ling et al. (2015), and Jena (2018), the model is represented by

$$EF_t = f(Z_t, EC_t, K_t, TO_t) \quad (4.1)$$

Since this study plan to measure the estimated coefficients, transformation of Eq. (4.1) into log linear form is recommended<sup>20</sup>. This specifies a constant elasticity over all values of the data set and have an interpretation as elasticities. This gives the per cent change in regression w.r.t to each regressor, more importantly, it overcomes the difficulty associated with the distributional properties of the variable series and makes the empirical results easy to interpret and comprehend. Thus, Eq. (4.2) illustrate log linear econometric model as follows:

$$\ln EF_t = \beta_1 + \beta_2 \ln Z_t + \beta_3 \ln Z_t^2 + \beta_4 \ln EC_t + \beta_5 \ln K_t + \beta_6 \ln TO_t + \varepsilon_t \quad (4.2)$$

Where  $\ln EF_t$  is the natural log of per capita EF measured in global hectares (gha),  $\ln Z_t$  (scale effect) is the natural log of real income,  $\ln Z_t^2$  (technique effect) is the natural log of the square term of real income measured in constant US dollar 2010,  $\ln EC_t$  is the natural log of per capita consumption of energy measured in kg of oil equivalent,  $\ln K_t$  (composition effect) is the natural log of capita-labour ratio,  $\ln TO_t$  is the natural log of trade openness measured as a percentage of gdp.  $\varepsilon_t$  is the residual term. The yearly data from 1991 to 2016 has been collected from different sources and agencies like data on real income, energy consumption and trade openness has been extracted from World Development indicator, data on EF has been collected from Global Footprint Network, and labour force, gross fixed capita formation data is taken from Penn World Table, version 9.1. Following Al-Mulali et al. (2015b), and Ulucak and Bolgili (2018) countries are categorised based on the income level of Asian countries into three sub groups (1) High income countries- Bahrain, Japan, Israel, Oman, Cyprus, Saudi Arabia, Korea republic, Brunei Darussalam, Singapore, United Arab Emirates (UAE), and Qatar. (2) Upper middle income countries- Jordan, Turkey, Lebanon, Iraq, Iran, Sri Lanka, China, Malaysia, Thailand, Kazakhstan, Armenia, Azerbaijan, and Turkmenistan. (3) Lower middle

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<sup>20</sup> A linear relationship provides us approximate explanation of some economic behaviour among the variables. The other feasible alternative is a log-log model where both explanatory as well as dependent variables are converted into log form. The difference between the linear model and log linear model is that former gives us marginal effect and later one as elasticities.

income countries-Bangladesh, India, Pakistan, Mongolia, Indonesia, Philippines, Vietnam, Kyrgyzstan, Uzbekistan, Myanmar, and Cambodia.

Since, this chapter employs panel data set, the application of ordinary least square (OLS) is asymptotically biased and its distribution depends upon the nuisance parameter. The nuisance parameter in the course of regression estimation, can result due to presence of endogeneity and serial correlation among the regressors. Therefore, to overcome these issues, fully modified ordinary least square (FMOLS) method is used suggested by Philips and Hansen (1990). This technique uses a nonparametric approach to address the issue of serial correlation and endogeneity Eq. (4.2), in the present analysis is examined for long run relationship among the variable via Fisher, Pedroni, and Kao cointegration test statistics. After finding cointegration among EF, scale effect, technique effect, energy effect, composition effect, and trade effect, long run results are estimated via panel FMOLS. Further, for robustness of the model DOLS are also tested.

#### 4.4: Result and Discussions

Table 4.1 presents descriptive test and correlation matrix analysis of Asian countries. The study find different level in per capita consumption of energy: 4.778 kg of oil equivalent is lowest and 10.004 is highest level.

**Table 4.1 Descriptive statistics and correlation matrix**

| Variables          | lnEF  | lnZ   | lnEC  | lnK   | lnTO  |
|--------------------|-------|-------|-------|-------|-------|
| Mean               | 1.01  | 8.49  | 7.37  | 11.30 | 4.19  |
| Median             | 0.98  | 8.37  | 7.32  | 11.51 | 4.36  |
| Maximum            | 2.83  | 11.17 | 10.00 | 13.92 | 6.08  |
| Minimum            | -0.76 | 5.24  | 4.77  | 6.87  | -3.86 |
| Std. Dev.          | 0.80  | 1.45  | 1.13  | 1.40  | 1.04  |
| Correlation matrix |       |       |       |       |       |
| lnEF               | 1.00  |       |       |       |       |
| lnZ                | 0.85  | 1.00  |       |       |       |
| lnEC               | 0.91  | 0.88  | 1.00  |       |       |
| lnK                | 0.75  | 0.85  | 0.77  | 1.00  |       |
| lnTO               | 0.33  | 0.33  | 0.32  | 0.40  | 1.00  |

Source: Author's calculation (2020)

Similarly, composition effect ranges from 6.876 to 13.925 and trade openness as a percentage of GDP ranges from – 3.863 to 6.080. EF per capita consumption and real income ranges from

– 0.766 to 2.830 and 5.247 to 11.175 respectively. All the variables in the correlation matrix are positively correlated.

**Table 4.2: Results from cross sectional independence test**

|                        | Breusch<br>Pagan LM | Pesaran<br>scaled LM | Bias-corrected<br>scaled LM | Pesaran<br>CD |
|------------------------|---------------------|----------------------|-----------------------------|---------------|
| Asian panel            |                     |                      |                             |               |
| lnEF                   | 5042.24*            | 127.90*              | 127.20*                     | 24.63*        |
| lnZ                    | 9929.63*            | 269.58*              | 268.88*                     | 74.32*        |
| lnZ <sup>2</sup>       | 9966.01*            | 270.63*              | 269.93*                     | 74.34*        |
| lnEC                   | 5113.09*            | 129.95*              | 129.25*                     | 18.35*        |
| lnK                    | 7544.01*            | 200.42*              | 199.72*                     | 38.75*        |
| lnTO                   | 3482.66*            | 82.69*               | 81.99*                      | 16.02*        |
|                        |                     |                      |                             |               |
| High income            |                     |                      |                             |               |
| lnEF                   | 379.64*             | 29.90*               | 29.68*                      | 4.55*         |
| lnZ                    | 565.90*             | 47.66*               | 47.44*                      | 6.74*         |
| lnZ <sup>2</sup>       | 565.43*             | 47.61*               | 47.39*                      | 6.67*         |
| lnEC                   | 333.37*             | 25.49*               | 25.27*                      | 2.76*         |
| lnK                    | 698.03*             | 60.26*               | 60.04*                      | 5.63*         |
| lnTO                   | 344.60*             | 26.56*               | 26.34*                      | 10.06*        |
|                        |                     |                      |                             |               |
| Upper middle<br>income |                     |                      |                             |               |
| lnEF                   | 668.50*             | 46.23*               | 45.97*                      | 14.52*        |
| lnZ                    | 1516.80*            | 114.15*              | 113.89*                     | 38.71*        |
| lnZ <sup>2</sup>       | 1524.85*            | 114.79*              | 114.53*                     | 38.82*        |
| lnEC                   | 683.29*             | 47.42*               | 47.16*                      | 12.44*        |
| lnK                    | 903.17*             | 65.02*               | 64.76*                      | 14.30*        |
| lnTO                   | 331.63*             | 19.26*               | 19.00*                      | 1.99**        |
|                        |                     |                      |                             |               |
| Lower middle<br>income |                     |                      |                             |               |
| lnEF                   | 572.01*             | 48.24*               | 48.02*                      | 11.03*        |
| lnZ                    | 1211.11*            | 109.18*              | 108.96*                     | 34.63*        |
| lnZ <sup>2</sup>       | 1222.03*            | 110.22*              | 110.00*                     | 34.80*        |
| lnEC                   | 601.13*             | 51.02*               | 50.80*                      | 7.04*         |
| lnK                    | 710.57*             | 61.45*               | 61.23*                      | 15.81*        |
| lnTO                   | 347.68*             | 26.85*               | 26.63*                      | 5.69*         |

Note: \* denote statistical significance at 1 per cent level.

Source: Author's calculation (2020)

Since this chapter employs panel data technique, it would therefore be imperative to check the data for cross sectional dependence (CSD) tests<sup>21</sup> to avoid any misspecification. Thus, this analysis applies four different cross sectional dependence test statistics and the outcome are

<sup>21</sup> Lagrange multiplier statistics proposed by Breusch, and Pagan (1980), and CSD test developed by Pesaran (2004).

presented in Table 4.2. Referring to probability value from the Table, the null hypothesis of independence cross sectional tests is rejected for EF, scale effect, technique effect, energy consumption, composition effect and trade openness at 1 or 5 per cent level of significance. Therefore the variables incorporated into the analysis have cross sectional dependence, thus this chapter proceed to use second generation CIPS and CADF unit root test which take both issues into account.

**Table 4.3: Results from panel unit root tests (Second generation test)**

|                     | CADF  |          | CIPS  |          |
|---------------------|-------|----------|-------|----------|
| Asian panel         | Level | $\Delta$ | Level | $\Delta$ |
| lnEF                | -2.44 | -2.97*   | -2.59 | -4.76*   |
| lnZ                 | -2.20 | -2.82*   | -2.12 | -3.72*   |
| lnZ <sup>2</sup>    | -2.17 | -2.69*   | -2.12 | -3.81*   |
| lnEC                | -2.10 | -3.09*   | -2.43 | -4.78*   |
| lnK                 | -1.71 | -2.29*   | -1.33 | -2.95*   |
| lnTO                | -2.03 | -3.65*   | -2.95 | -4.29*   |
|                     |       |          |       |          |
| High income         |       |          |       |          |
| lnEF                | -1.50 | -3.13*   | -1.66 | -5.30*   |
| lnZ                 | -1.34 | -2.35*   | -1.29 | -3.72*   |
| lnZ <sup>2</sup>    | -1.65 | -3.12*   | -1.28 | -3.73*   |
| lnEC                | -1.16 | -3.10*   | -1.36 | -4.78*   |
| lnK                 | -1.43 | -2.22*   | -1.00 | -2.42*   |
| lnTO                | -2.20 | -3.31*   | -2.21 | -4.33*   |
|                     |       |          |       |          |
| Upper middle income |       |          |       |          |
| lnEF                | -2.25 | -2.73*   | -2.77 | -4.74*   |
| lnZ                 | -2.22 | -2.80*   | -2.28 | -3.95*   |
| lnZ <sup>2</sup>    | -2.05 | -2.76*   | -2.18 | -3.90*   |
| lnEC                | -2.24 | -2.77*   | -2.81 | -4.61*   |
| lnK                 | -1.11 | -2.45*   | -0.85 | -3.22*   |
| lnTO                | -1.99 | -2.80*   | -1.82 | -4.03*   |
|                     |       |          |       |          |
| Lower middle income |       |          |       |          |
| lnEF                | -1.89 | -2.88*   | -1.91 | -4.74*   |
| lnZ                 | -1.89 | -2.86*   | -2.12 | -3.38*   |
| lnZ <sup>2</sup>    | -2.01 | -2.79*   | -2.13 | -3.32*   |
| lnEC                | -1.20 | -2.89*   | -1.38 | -4.24*   |
| lnK                 | -1.21 | -2.25*   | -1.22 | -2.52*   |
| lnTO                | -1.38 | -3.14*   | -1.81 | -4.53*   |

Note:  $\Delta$  denotes the first differences,\* denote the statistical significance at 1 per centlevel.

Source: Author's calculation (2020)

#### 4.4.1: Unit root analysis

This study prefer CIPS and CADF unit root statistics developed by Pesaran (2007) to ones such that augmented Dickey–Fuller (ADF), and Phillips-Perron (PP) unit root of first generation. Given the drawbacks of assuming homogeneity and cross-sectional independence, the first generation test is likely to produce inefficient results. As these unit root test fails to take the issues of cross sectional dependence into account, hence this study used the CIPS and CADF statistics which gives reliable outcome in the presence of both heterogeneity and CSD. The unit root results of second generation for Asian panel, high income, upper middle and lower middle income countries are shown in Table 4.3. Both tests indicate that EF, scale effect, technique effect, energy consumption, composition effect and trade openness are not stationary (unit root) at their level form but at their first difference they become stationary (no unit root), therefore the considered variables are integrated of order one  $I(1)$ . For economically and statistically meaningful long run coefficient estimates of the regressor, the panel data either should be stationary or cointegrated at their levels. Because EF, Z,  $Z^2$ , EC, K, and TO contains unit root at their level form, this empirical chapter uses three prominent cointegration analysis: such as Fisher-type Johansen cointegration analysis, Kao cointegration test, and the Pedroni cointegration test to analyze the long run association between the variables of Eq. (4.2).

#### 4.4.2: Cointegration analysis

Further, this study searches for possible long run association among the examined variables firstly by employing the Pedroni cointegration test due to Pedroni (1999)<sup>22</sup> in Asian panel, high income, upper middle and lower middle income countries. The Pedroni cointegration statistics consist of seven tests out of which four test are within dimension approach and three are between dimension approaches as shown in Table 4.4. The findings from pedroni long run relationship show four out of seven tests are statistically significant at 1, 5 and 10 per cent level of significance, which confirms the majority of the test statistics in Asian panel, high income, upper middle, and lower middle income countries are cointegrated and exhibits long run relationship among analysed variables.

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<sup>22</sup> This tests is applicable for heterogeneous panels.

**Table 4.4: Results from Pedroni cointegration test**

| Panel: A Pedroni cointegration test     | Asian panel | High income | Upper middle income | Lower middle income |
|-----------------------------------------|-------------|-------------|---------------------|---------------------|
| Common AR coefs (within dimension)      | Statistics  | Statistics  | Statistics          | Statistics          |
| Panel v-statistics                      | -0.45       | -0.74       | 0.64                | -1.30               |
| Panel rho-statistics                    | 1.44        | 1.12        | 0.06                | 1.72                |
| Panel PP-statistics                     | -5.16*      | -1.90**     | -6.32*              | -1.54***            |
| Panel ADF-statistics                    | -6.43*      | -2.47*      | -6.69*              | -1.88**             |
|                                         |             |             |                     |                     |
| Individual AR coefs (between dimension) |             |             |                     |                     |
| Group rho-statistics                    | 3.41        | 1.58        | 1.84                | 3.27                |
| Group PP-statistics                     | -6.05*      | -3.61*      | -5.45*              | -4.29*              |
| Group ADF-statistics                    | -8.17*      | -4.28*      | -6.28*              | -3.22*              |
|                                         |             |             |                     |                     |

Note: \*, \*\* & \*\*\* denote the statistical significance at 1, 5 and 10 per cent level respectively

Source: Author's calculation (2020)

**Table 4.5: Results from Kao and Johansen Fisher cointegration tests**

|                                    | Asian panel  |                 | High income  |                 | Upper middle income |                 | Lower middle income |                 |
|------------------------------------|--------------|-----------------|--------------|-----------------|---------------------|-----------------|---------------------|-----------------|
| Augmented Dickey-Fuller (ADF) test | t-statistics |                 | t-statistics |                 | t-statistics        |                 | t-statistics        |                 |
|                                    | -7.63*       |                 | -3.68*       |                 | -8.18*              |                 | -3.91*              |                 |
| Fisher cointegration rank test     |              |                 |              |                 |                     |                 |                     |                 |
| Hypothesized no. of CE(s)          | Trace value  | Max Eigen value | Trace value  | Max Eigen value | Trace value         | Max Eigen value | Trace value         | Max Eigen value |
| $r = 0$                            | 1396.0*      | 726.4*          | 412.3*       | 216.5*          | 550.0*              | 297.8*          | 434.1*              | 212.0*          |
| $r \leq 1$                         | 826.3*       | 408.3*          | 235.7*       | 125.0*          | 319.2*              | 148.8*          | 271.4*              | 134.5*          |
| $r \leq 2$                         | 499.4*       | 272.9*          | 133.5*       | 78.91*          | 200.5*              | 104.8*          | 165.4*              | 89.19*          |
| $r \leq 3$                         | 287.2*       | 180.7*          | 73.36*       | 47.48*          | 117.2*              | 71.45*          | 96.65*              | 61.80*          |
| $r \leq 4$                         | 177.5*       | 153.5*          | 46.86*       | 34.5**          | 71.65*              | 68.41*          | 58.99*              | 50.57*          |
| $r \leq 5$                         | 126.3*       | 126.3*          | 50.81*       | 50.8*           | 37.51***            | 37.51***        | 37.9**              | 37.9**          |

Note: \*, \*\* & \*\*\* denote the statistical significance at 1, 5 and 10 per cent level respectively.

Source: Author's calculation (2020)

Secondly, the Panel Kao cointegration tests proposed by Kao (1999) includes cross homogeneous coefficients and follows the similar procedure as the Pedroni test on the first stage regressors. Referring to the associated p values in Table 4.5, the null hypothesis of no



cointegration is highly rejected at 1 percent significance level which indicate the analysed variables in all the group panels are cointegrated and have long run relationship. The third test is applied is Johansen Fisher cointegration test developed by Maddala and Wu (1999)<sup>23</sup>. The empirical results are presented in lower panel of Table 4.5, which shows that there is significant long run relationship among ecological footprint, scale effect, technique effect, energy consumption, composition effect, and trade openness in all the sub panels.

#### **4.4.3: Long-run results**

After the study confirm that scale effect, technique effect, energy consumption, composition effect, and trade openness has a long run relationship in Asian panel, high income, upper middle and lower middle income countries, then comes an important inference for researchers to analyse the long run coefficients of the regressors. The literature uses OLS which is very popular and commonly used ones; however, the DOLS and FMOLS techniques have been recently preferred over OLS method (Lee et al., 2009). These estimators have advantage in eliminating autocorrelation problem in the residual terms and endogeneity issues in the explanatory variables (Bhattacharya et al., 2016). In addition, by using parametric approach DOLS methods gets rid of the problem of its lags and leads of the regressors while the FMOLS technique eliminates the problem of serial correlation and endogeneity. It appears that income level is important in testing the trade-emissions nexus. To be able to reach homogeneous income level estimations, we classified countries into three sub panels as mentioned before; high income, upper middle and lower middle income countries by employing FMOLS and the DOLS approach.

The empirical findings from FMOLS and DOLS estimators are provided in Table 4.6 and 4.7 respectively. The coefficient described are statistically significant at 1, 5 and 10 per cent level. Because the panel time series variables are in natural log, the long run EF with respect to scale effect, technique effect, energy consumption, composition effect, and trade openness are econometrically equal to the elasticities of EF. Although, the coefficient magnitudes in all panels differ across the considered estimators, the results of FMOLS is same as the DOLS<sup>24</sup>. The empirical finding reveals that while achieving economies of scale, the coefficient estimates of scale effect is positive on EF. However, when there is a changes in technology because of

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<sup>23</sup> This tests is based on the aggregated p values showing trace statistics and maximum eigenvalues individually and depends heavily on the number of lags of the vector autoregressive system.

<sup>24</sup> In case of DOLS some variables are insignificant but signs are same as in FMOLS.

the transition in economy of scale this effect turns from positive to negative, where upsurge in real income reduces environmental pollution, though their magnitudes of estimated coefficients changes across the four sub panels. More precisely, the marginal effect of scale on  $EF$  is computed by  $\beta_1 + 2\beta_2 Y$  show that the outcome of scale effect on  $EF$  is clearly positive in the early stage of economic development, but it decreases and eventually becomes negative as they shift to technology-based economic growth.

**Table 4.6: Results from Fully modified OLS**

|                | Asian panel |        | High income |         | Upper middle income |         | Lower middle income |        |
|----------------|-------------|--------|-------------|---------|---------------------|---------|---------------------|--------|
| Variables      |             |        |             |         |                     |         |                     |        |
|                | Coeff       | Prob.  | Coeff       | Prob.   | Coeff               | Prob.   | Coeff               | Prob.  |
| $\ln Z$        | 0.56        | 0.00*  | 4.99        | 0.00*   | 1.48                | 0.00*   | 1.52                | 0.00*  |
| $\ln Z^2$      | -0.02       | 0.00*  | -0.12       | 0.04**  | -0.08               | 0.00*   | -0.04               | 0.00*  |
| $\ln EC$       | 0.65        | 0.00*  | 0.37        | 0.00*   | 0.66                | 0.00*   | 0.43                | 0.00*  |
| $\ln K$        | 0.04        | 0.00*  | -0.13       | 0.00*   | -0.03               | 0.08*** | -0.11               | 0.00*  |
| $\ln TO$       | -0.01       | 0.04** | -0.11       | 0.07*** | -0.01               | 0.00*   | 0.06                | 0.02** |
| $R^2$          | 0.98        |        | 0.87        |         | 0.95                |         | 0.98                |        |
| Adjusted $R^2$ | 0.98        |        | 0.85        |         | 0.95                |         | 0.98                |        |
| Obs.           | 875         |        | 275         |         | 325                 |         | 275                 |        |

Note:  $EF$  is the dependent variable. \*, \*\* & \*\*\* denote the statistical significance at 1, and 10 per cent level respectively. *Coeff.* Coefficient, *Prob.* Probability value.

Source: Author's calculation (2020)

In other words, increase in the economies of scale leads to environmental improvements as the Asian countries, high income, upper middle, and lower middle income countries pass the threshold income level (technology effect). This shows that the linear and nonlinear association between scale and technique effect in terms of economic growth and  $EF$  is 'inverted U-shaped', this validate the presence of EKC hypothesis in all four panels. Our empirical findings suggest that rise in economic activity does not deteriorate environmental quality of Asian countries this is because income encourages the adoption of newer technology which leads to cleaner production. This empirical evidence of EKC is in line with Asici and Acar (2016), Mrabet and Alsamara (2017), Charfeddine and Mrabet (2017), Ulucak and Bilgili (2018), Hassan et al. (2019), Fakher (2019). On the contrary, Begum et al. (2015) analysed the dynamic impact of economic growth, energy consumption on  $CO_2$  emissions using ARDL approach spanning the period 1980–2009. Their empirical finding showed per capita  $CO_2$  emissions decreased with

increasing economic growth and increased sharply with a further increase of per capita GDP which did not support the EKC hypothesis in Malaysia. Similarly, Destek et al. (2018) and Ansari et al. (2020) also examines the EKC for European and top CO<sub>2</sub> emitter countries respectively. Their empirical finding showed U-shaped relationship between the real income and EF. Furthermore, this study are similar to the study of Tsurumi and Managi (2010), Zhang (2012), Ling et al. (2015), and Jena (2018) who also examined the impact of scale, technique and composition effect on environmental degradation and found that scale effect ultimately degrades the quality of environment while technique effect improves the environmental quality in the long run.

Regarding the impact of energy consumption on EF, increase in consumption of energy stimulates the environmental pollution. A 1 per cent increase in EC boosts EF by 0.05 per cent–0.66 per cent. This empirical outcome is same as reported by Ling et al. (2015), Dogan and Seker (2016b), Destek et al. (2018), Ahmed et al. (2019). The energy consumption is required to achieve the level of economic growth, as these nations are characterised by high economic growth. The existing renewable energy solutions are not yet mature enough to fulfil the present level of demand of energy, as these nations mostly rely on the fossil fuel energy solution (Sinha, 2017). Because usage of energy is a necessary and an important source in the production process, it is quite impossible for countries to stop using energy. This continued consumption of fossil fuel has created a disturbance in the environment by resulting in rise in the EF. So for ensuring clean and sustainable development, these income group countries are advised to increase the share of consumption of renewable energy as well as to increase the energy efficiency level. Referring to Apergis and Ozturk (2015) who suggested that increase in the consumption of bio-diesel fuels stimulate environmental problem whereas increase in consumption of renewable energy like wind and solar energy projects lessen the environmental pollution in Asian countries. Jebli et al. (2016) explored that renewable energy consumption decreases the EF whereas use of non-renewable energy increases them. This indicate that use of renewable energy is an environmentally sustainably source on which the policy adviser should focused more on for the sake of environmental quality. Therefore, the Asian countries should focused more on the development of techniques for increased consumption of renewable energy, energy efficiency and green investments through environmental technologies.

The elasticity of EF with respect to composition effect is negative and statistically significant meaning that capital-labour ratio require lower level of EF except for Asian panel. The results

show that 1 per cent increase in composition effect (capital-labour ratio) lead to decrease in EF ranges from  $-0.03$  to  $-0.49$  percent. This negative relationship between composition effect and environmental degradation is in line with those of Tsurumi and Managi (2010), and Ling et al. (2015), who also report that increase in composition effect, will upsurge EF in high income countries and China respectively, but opposite to those of Cole (2006), Zhang (2012), Jena (2018), who analysed the impact of scale, technique, and composition effect on environmental degradation and found positive relationship between composition effect and environmental pollution. This findings further reveals that using more of labour intensive technique means of production (i.e change in the composition of production line), reduces carbon intensity in the presence of technique effect. Furthermore, Managi et al. (2009) have argued that the previous empirical studies treated per capita income and trade openness variables as exogenous. Income and production level of a country are also affected by the openness in trade this is because in reality, the degree of trade openness can be influence by the economic growth of that country which have not been taken into account by previous literatures. Due to these specification errors, they<sup>25</sup> believe that the trade induced technique and scale effects cannot be compared with the trade induced composition effect to reach at an overall trade openness effect. In this argument there is a strong reasoning, as per capita income increases, there is rise in technique effect, which also affects the composition of output through environmental regulation-induced comparative advantage. Hence, composition effect is not fully independent of the income effect.

Given these empirical findings, this chapter argue that openness in trade has a negative and significant effect on EF in all the income based Asian panels except in the case of lower middle income countries. The coefficient elasticities of EF with respect to trade openness ranges between  $(-0.01)$  and  $(-0.11)$ . This shows that rise in trade openness mitigate EF in Asian panel, high income and upper middle income countries. It suggests that trade liberalization in case of Asian and other income group countries is a long run phenomenon. Over the last several years, particularly developed nations have made a great achievement in developing new technologies and the examined these income group countries seem to take advantage of capital formation, technology and institutional spill over via trade development. Moreover, these countries are likely to produce environment friendly goods and export non-energy intensive products. It seems that the dirty and environmentally-unfriendly goods operated in Asian panel,

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<sup>25</sup> Tsurumi and Managi (2010); Managi et al. (2009).

high, and upper middle income countries relocate their dirty factories to underdeveloped or less developed countries relatively with less stringent environmental regulations and enforcements, this phenomena is known as PHH<sup>26</sup>. Therefore, to enhance environmental quality, long term national policies will increase trade volume in these countries. This negative association between TO and EF is consistent with the findings of Mrabet and Alsamara (2017), Destek et al. (2018), Destek and Sinha (2020) for Qatar, European, and 24 OECD countries. However, significant and positive association was found between TO and EF in the case of lower middle income countries. This findings indicate that the pollution industries are more likely to move from developed to lower middle income Asian countries because the environmental regulations in these income countries are weak and less stringent, hence support PHH. Similar results were reported by Al-Mulali et al. (2015a), Figge et al. (2017), Uddin et al. (2017), and Sabir and Gorus (2019). The reported results also reveal goodness of fit of the specification ( $R^2$ ) ranges from 0.87 to 0.99 which implies that the changes in the dependent variables are well enough explained by the independent variables.

**Table 4.7: Results from Dynamic OLS**

|                         | Asian panel |       | High income |         | Upper middle income |        | Lower middle income |         |
|-------------------------|-------------|-------|-------------|---------|---------------------|--------|---------------------|---------|
| Variables               |             |       |             |         |                     |        |                     |         |
|                         | Coeff       | Prob. | Coeff       | Prob.   | Coeff               | Prob.  | Coeff               | Prob.   |
| lnZ                     | 1.13        | 0.00  | 5.74        | 0.09*** | 2.16                | 0.00*  | 0.73                | 0.05*** |
| lnZ <sup>2</sup>        | -0.05       | 0.00* | -0.27       | 0.09*** | -0.12               | 0.01** | -0.01               | 0.68    |
| lnEC                    | 0.43        | 0.00* | 0.22        | 0.05*** | 0.62                | 0.00*  | 0.17                | 0.00*   |
| lnK                     | 0.18        | 0.00* | -0.49       | 0.00*   | -0.03               | 0.59   | -0.14               | 0.00*   |
| lnTO                    | -0.03       | 0.00* | -0.08       | 0.20    | -0.03               | 0.01** | 0.005               | 0.05*** |
| R <sup>2</sup>          | 0.99        |       | 0.98        |         | 0.99                |        | 0.99                |         |
| Adjusted R <sup>2</sup> | 0.99        |       | 0.92        |         | 0.98                |        | 0.99                |         |
| Obs.                    | 805         |       | 253         |         | 299                 |        | 253                 |         |

Note: EF is the dependent variable. \*, \*\* & \*\*\* denote the statistical significance at 1, and 10 per cent level respectively. *Coeff.* Coefficient, *Prob.* Probability value.

Source: Author's calculation (2020)

The empirical findings are reliable, robust and strong since we used various cross sectional dependence test, unit root analysis, cointegration statistics, and long run approaches. Although this chapter employed longest available data for the sample countries on the analysed countries, once the longer data become available further studies can potentially obtain more robust results.

<sup>26</sup> When large industrialized countries seek to set up offices or factories abroad, they often look for the cheapest options in terms of resource and labour.

Moreover, the study employed second generation tests where the outcome of one is confirmed by the other test statistics in the same group (Table 4.7)

#### 4.4.4: Panel granger causality test

In the panel data, granger causality is computed by running bivariate regressions which takes the form

$$X_{it} = \alpha_{0i} + \alpha_{1i}X_{it-1} + \dots + \alpha_{ki}X_{it-k} + \beta_{1i}Y_{it-1} + \dots + \beta_{ki}Y_{it-k} + \varepsilon_{it} \quad (4.3)$$

$$Y_{it} = \alpha_{0i} + \alpha_{1i}Y_{it-1} + \dots + \alpha_{ki}Y_{it-k} + \beta_{1i}X_{it-1} + \dots + \beta_{ki}X_{it-k} + \varepsilon_{it} \quad (4.4)$$

Where, i indicates the cross sectional dimension, and t indicates the time period dimension. The panel causality test of different forms differ on the assumption made about the homogeneity of the coefficients across cross sections.

**Table 4.8: Results from Pairwise Granger causality tests**

|                               | Asian panel  | High income  | Upper middle income | lower middle income |
|-------------------------------|--------------|--------------|---------------------|---------------------|
| Null Hypothesis: No causality | F-Statistics | F-Statistics | F-Statistics        | F-Statistics        |
| lnZ → lnEF                    | 10.63*       | 0.10         | 6.84*               | 5.33*               |
| lnEF → lnZ                    | 0.99         | 0.24         | 0.07                | 1.38                |
| LnZ <sup>2</sup> → lnEF       | 9.96*        | 0.08         | 6.15*               | 6.21*               |
| lnEF → lnZ <sup>2</sup>       | 0.31         | 0.18         | 0.05                | 1.14                |
| lnEC → lnEF                   | 8.47*        | 7.49*        | 12.32               | 6.53*               |
| lnEF → lnEC                   | 0.92         | 0.89         | 2.64***             | 1.32                |
| lnK → lnEF                    | 6.77*        | 0.66         | 1.31                | 0.09                |
| lnEF → lnK                    | 7.36*        | 2.33***      | 5.80*               | 0.68                |
| lnTO → lnEF                   | 0.63         | 0.51         | 6.54*               | 0.16                |
| lnEF → lnTO                   | 4.33**       | 2.73***      | 1.85                | 0.21                |
| lnEC → lnZ                    | 6.45**       | 0.86         | 0.48                | 2.77***             |
| lnZ → lnEC                    | 17.65        | 5.45*        | 9.20*               | 4.54**              |
| lnK → lnZ                     | 1.49         | 6.21*        | 1.33                | 1.44                |
| lnZ → lnK                     | 43.25        | 0.34         | 9.07*               | 8.57*               |
| lnTO → lnZ                    | 8.98*        | 1.56         | 7.16*               | 1.46                |
| lnZ → lnTO                    | 4.59**       | 0.77         | 0.77                | 0.72                |
| lnK → lnEC                    | 16.37        | 5.37*        | 3.12**              | 2.84***             |
| lnEC → lnK                    | 2.35         | 0.28         | 6.69*               | 0.16                |
| lnTO → lnEC                   | 0.42         | 0.81         | 11.00               | 0.97                |
| lnEC → lnTO                   | 4.03**       | 0.22         | 2.66***             | 0.06                |
| lnTO → lnK                    | 3.56***      | 0.003        | 0.83                | 4.89*               |
| lnK → lnTO                    | 6.77*        | 1.39         | 0.12                | 5.23*               |

Note: \*, \*\* & \*\*\* denote the statistical significance at 1, 5 and 10 per cent level respectively. Lags are auto-selected.

Source: Author's calculation (2020)

For analysing the causal relationship among the variables, this chapter conducted the pair-wise Granger causality test. The results presented in Table 4.8 show that scale effect granger causes EF in the long run. This unidirectional of causality running between  $Z$  and  $EF$  confirms the existence of EKC hypothesis (Narayan and Narayan, 2010) in all the Asian income group countries including Asian panel. There is one way granger causality running from technique effect ( $Z^2$ ) to EF in all income panels except high income countries. The results further suggest that there is causality running from energy consumption to EF in Asian panel, high income and lower middle income, however, in the case of upper middle income group there is bidirectional causality exist running from  $EC$  to  $EF$ , this indicate that consumption of energy are the major cause for environmental degradation in the panel countries. These empirical outcomes are consistent with Ling et al. (2015) and Dogan and Seker (2016a). Moreover the feedback exist between composition effect and EF in case of Asian panel countries where trade openness causes EF only in upper middle income countries<sup>27</sup>.

#### 4.5: Conclusion and policy recommendations

This chapter attempts to investigate a question whether international trade obstruct environmental quality or not in case of Asian income group countries; Asian panel, high income, upper middle, and lower middle income countries spanning the period of 1991–2016. Since majority of studies have used CO<sub>2</sub> emissions as an indicator of environmental quality, we have employed EF function by incorporating energy consumption, scale effect, technique effect, trade openness, and composition effect. For this purpose, the CIPS and CADF unit root test is applied to test the stationary properties of the variables and three different approach to panel cointegration tests is used to examine the presence of long run relationship among EF, scale effect, energy consumption, technique effect, composition effect and trade openness. The findings revealed the confirmation of cointegration among the variables. The scale effect significantly and positively increases EF while technique effect has negative impact on EF which lowers environmental degradation in all Asian income group countries. Use of energy (energy effect) increases EF, but composition effect lowers EF in all income group. Trade effect reduces EF in high income, and upper middle income while it increases in lower middle income countries. In addition, the granger causality reveals scale effect, composition effect

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<sup>27</sup> This finding is similar to Lau et al. (2014)

cause EF and hence EF. Moreover, energy consumption and technique effect granger causes to EF.

From the policy perspective, the results of this chapter indicate that under self-correcting mechanism income works, where, due to scale effect there is environmental degradation as it get improved later due to technique effect. This implies that present environmental policies adequately lowers environmental outcome of development process in all the Asian income countries. However, the granger causality running from composition effect to energy use aware toward structural gaps in policy implications in case of Asian countries. The substitution of non-renewable energy sources with non-conventional sources/renewable energy necessarily may not lower EF provided technique effect sufficiently assist the composition effect. In order to maintain efficiency level, it is important to adopt new and updated technology and significantly shifting from non-renewable to nonconventional source of energy is equally important. Protecting the country from outdated dirty products which comes at the cost of environmentally unsound practices is also an important measures to be taken care off.

In addition, findings also show that liberalization in trade policy lowers environmental degradation and supports economic growth in high income, and upper middle income countries of Asia. This further implies that more openness in trade cause comparative advantage among the trading partner countries which helps in combating greenhouse gas emissions in these income group economies. On the other hand, trade increases environmental pollution in lower middle income countries. These empirical findings enable government official/policy makers to redirect the trade-induced investment inflow and technical change toward improved and better policy framework that can meet sustainable development goals followed by growth oriented policies. Reforms in the energy division section are important in order to overcome the problem associated with negative effect of environment on economic growth in Asian countries. This chapter does not only provide adequate policy implications that encourage sustainable economic development in high income, upper middle and lower middle income countries of Asia, but also fill the existing gap on the pollution-growth nexus literature

Moreover, our empirical work also provide two key characteristic points in the existing literature on EKC framework; first, it declares presence of EKC hypothesis in all the income group of Asia such as Asian panel, high income, upper middle income, and lower middle income countries, and secondly, it concludes with the sign of granger cause between the



analysed variables. We further decompose EKC model and empirically test the environmental consequences of scale, composition, and technique effect. The reported findings are reliable, robust and strong since we use different econometric techniques and results hold appropriate policy implications for Asian sub panels and helps strategy planner in numerous ways.

## **Chapter 5**

### **Findings, Conclusion and Policy Implications**

#### **5.1: Introduction**

The world is confronted with the surge in greenhouse gas emissions and sustaining economic growth. With the rapid rise in the global warming, the environment has come to the forefront of the contemporary issues both for developed and developing nations. This has resulted due to the extensive use of natural resources and fossil-fuels to enlarge the production level. Over the decades, the world has experienced significant growth in economic and social development and consequentially moved toward resource and energy-intensive lifestyle. According to the World Bank, approximately 70 per cent of energy demand fulfil by fossil fuels. Therefore the focus has been given on the role of energy conservation, pollution control and renewable energy to reduce the environmental impact of such a lifestyle.

Recent research shows voluminous studies was conducted to devise the plan for suitable policy implication. Further, it has attracted the attention of the researcher to investigate the relationship between foreign direct investment (FDI), economic growth, and trade on environmental degradation. Various scenario-based forecasting and empirical analysis have been attempted in different regions and countries. In such scenario, developed countries is more abundant with cleaner technology and with high energy efficiency as compared to developing countries. It is seen that developing countries prioritise economic growth without proper preservation of environment. It damages their eco-system as the burden exceeds the reproductive capacity of eco-system. To pursue sustainable development, it requires focusing on energy saving through eco-friendly technology.

The interest of this thesis lies in three ways. First, Asia is now the largest recipient and accounts for almost one-third of total FDI inflows. The economic diversification had become a main economic and political priority in the Asian economies. FDI inflows to developing Asia are expected to increase, as an improved economic outlook in major Asian economies is likely to boost investor confidence in the region since they are moving towards more economic liberalisation. Second, Asia's ecological footprint (EF) continues to rise at a faster pace than Earth's bio capacity in these regions and relatively higher than all other regions. Furthermore, EF shows considerable variabilities across Asian regions. This is mainly due to sharp increase in population, higher growth of consumption expenditure for increase economic development

and decline in the productive ecological resources along with inadequate resource management, habitat destruction and environmental pollution. Lastly, the examination of the Asian countries is of interest of policy makers and researchers since carbon emissions over the past few decades are highly rising as compared to the rest of the world according to the World Development Indicator, where carbon component makes 47 per cent or more of the total EF. Moreover, per capita EF consumption (1.6 global hectares (gha)) in these countries, according to the global footprint network far exceeds the available bio capacity per capita (0.9 gha), leaving the bio capacity deficit of 0.8 gha per capita.

On this background, a great majority of literature has examine the validity of pollution haven hypothesis (PHH) and environmental Kuznets curve (EKC) hypothesis in various time series and panel data cases, but the studies at sub panel of Asian regions together have not been analysed. While vast amount of literature has analysed the impact of aggregate trade effect<sup>28</sup> on the environmental quality. Primarily in this study decomposition analysis has been conducted to decompose trade effect into scale, technique and composition effect<sup>29</sup>. Trade inflow in these group countries is showing increasing trend in each income group. This implies that that high income countries of Asia are more openness to trade than upper middle and lower middle income countries which might have adverse effect on the environment.

In carrying out their research, the literature have mostly considered CO<sub>2</sub> emission as a proxy for environmental quality to measure the greenhouse gas (GHG) emission. Given the fact that CO<sub>2</sub> emission is the primary cause of climate change, majority of studies used it as an indicator of environmental pollution. However it is criticized to use it as sole proxy of environmental pollution. Since it ignore other major pollutant which too contributes to environmental deterioration such as degradation in mining, forestry land, oil, grazing land, water pollution and so forth is extremely important. So outcome may be misleading when using CO<sub>2</sub> emissions solely as proxy for environmental pollution. Therefore, one must use inclusive environmental indicator to obtain better understanding between economic growth, trade and environmental damage to the country. For this purpose the study employed EF indicator to compute cumulative human pressure on the environment.

From an economic perspective, this study has investigated the impact of economic growth and trade openness on environmental degradation using EF indicator to measure the emissions level

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<sup>28</sup> Export plus import as percentage of GDP

<sup>29</sup> Only few studies analyse this study

which is more comprehensive measure of environmental pollution. Moreover, it appears that grouping on the basis of income is an important factor, therefore to reach out the income level homogenously, we grouped Asian countries into high income, upper middle and lower middle income countries for better policy implications.

There is extensive literature on the relationship between FDI, economic growth and trade openness on environmental degradation in case of developed and developing countries. To the best of author's knowledge there is no single study that examines these issues in case of sub regions of Asian countries and income based approach studies together from an economic point of view. Therefore, there is need to undertake a comprehensive study to evaluate the FDI, economic growth and trade openness performance of Asian countries. With this background the main objective of this thesis is:

- (a) To analyse the impact of foreign direct investment on environmental quality performance of Asian countries at sub regional level.
- (b) To analyse the linkage between economic growth and environmental degradation of Asian countries across different sub regions
- (c) To analyse the impact of trade openness on the environmental quality based on the income group of Asian economies

## **5.2: Findings**

### **5.2.1: Chapter 2**

This chapter investigate the validity of the PHH for the Asian panel consisting of 29 countries (Bahrain, Israel, Jordan, Saudi Arabia, Turkey, United Arab Emirates, Oman, Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, Uzbekistan, China, Japan, Mongolia, Hong Kong, Korea rep, Bangladesh, India, Pakistan, Sri Lanka, Nepal, Iran, Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam) are taken as the sample of this study with energy consumption, economic growth and trade openness as additional determinants of environmental degradation over the period 1994–2014. To make the panel data analysis more homogenous, the chapter also investigate the validity of the PHH for a number of sub-panels. These sub-panels are constructed based on the sub-regions of Asia. In this way, five Asian panels; namely, West Asia, Central Asia, East Asia, South Asia and Southeast Asian panels were grouped. Data has been extracted from the World development Indicator for the sample.

Based on the Im-Pesaran-Shin and Augmented Dickey Fuller chi-square unit root test and Pedroni cointegration test results, all variables were found to be first difference stationary and cointegrated. On applying fully modified ordinary least square, the long-run results suggest the presence of the PHH only in East Asian panel. In turn, FDI reduces environmental degradation, thus rejecting the validity of the PHH in the Southeast Asian panel which is found to be negatively linked to CO<sub>2</sub> emissions. Moreover, energy consumption seems to be the main determinant of carbon emissions and economic growth has a positive impact on it in all panels except West Asia.

### ***5.2.2: Chapter 3***

This chapter employed EF indicator as a proxy for environmental quality from the consumption perspective as a holistic measure of human pressure on the environment to examine the economic growth- environment nexus. Particularly, EKC hypothesis has been tested for the group of thirty-seven Asian countries. These are further analysed into five Asian sub-regions, namely; West-, Central-, South-, East-and Southeast Asian countries over the period of 1991 to 2017. Panel cointegration, Pooled mean group, and dynamic ordinary least square have been applied. The analysis reveals a mixture of results for the presence of EKC when using EF. EKC exists for Central-and East Asian countries, but not in case of West-, South-and Southeast Asian countries. Energy consumption increases the EF. In addition, overall globalization and urbanization enhances EF. From the outcome of this empirical work, a number of policy recommendations have been discussed.

### ***5.2.3: Chapter 4***

This chapter empirically examines the impact of trade openness on EF employing panel data time series covering the period 1991–2016 for the sample of thirty five Asian countries. To analyse the consequence of trade at three distinct transition points, we decompose the trade effect into scale, composition, and technique effects. Using second generation econometric approaches that considers the issue of cross sectional dependence, the result show positive (negative) effect of scale (technique) on EF which validates the EKC hypothesis for high income, upper middle and lower middle income countries. Further, energy consumption contribute to EF whereas, composition effect and trade openness mitigates environmental degradation. However, the results vary across different sub-panels. The findings impart innovative approach to detect the influence of trade openness in three sub dimensions of trade

liberalization. Hence, for trade policy makers and economists, this article assigns more comprehensive policy implications and suggest sustainable trade agreements among the region.

### **5.3: Policy Implications**

From the policy perspective, this thesis provides important insights for implementing a nuanced FDI, economic growth, trade and environmental degradation. Since FDI impedes the environment quality in East Asian countries. As FDI particularly increases pollution, more environmental preservation efforts are needed in East Asia. These countries should encourage the use of environment-friendly technologies to enhance domestic production. The governing bodies should also stop licensing polluting industries such as chemical and pharmaceutical firms and boundries, which emit more CO<sub>2</sub> emissions comparatively. Therefore these polluting firms must be regularly assessed for their environmental impact.

Sustainable development goals (SDGs) and meeting the Paris agreement especially is an important to reduce EF in these sub regional countries. This can be achieved through, energy security, reducing environmental pollution and providing access to modern energy, reducing the non-renewable energy consumption, in particular oil and coal and at the same time increasing the usage of renewable energy source. Further, for achieving Paris agreement goal, removal of subsidies and carbon pricing model play an important role in retaining sustainable development objectives.

Moreover, from trade-environment nexus point of view, the results indicate that under self-correcting mechanism income works, where, due to scale effect there is environmental degradation as it get improved later due to technique effect. This implies that present environmental policies adequately lowers environmental outcome of development process in all the Asian income countries. However, the granger causality running from composition effect to energy use aware toward structural gaps in policy implications in case of Asian countries. The substitution of non-renewable energy sources with non-conventional sources/renewable energy necessarily may not lower EF provided technique effect sufficiently assist the composition effect. In order to maintain efficiency level, it is important to adopt new and updated technology and significantly shifting from non-renewable to nonconventional source of energy is equally important. Protecting the country from outdated dirty products which comes at the cost of environmentally unsound practices is also an important measures to be taken care off.

In addition, findings also show that liberalization in trade policy lowers environmental degradation and supports economic growth. This further implies that more openness in trade cause comparative advantage among the trading partner countries which helps in combating greenhouse gas emissions in these income group economies. On the other hand, trade increases environmental pollution in lower middle income countries. These empirical findings enable government official/policy makers to redirect the trade-induced investment inflow and technical change toward improved and better policy framework that can meet SDGs followed by growth oriented policies. Reforms in the energy division section are important in order to overcome the problem associated with negative effect of environment on economic growth in Asian countries.

#### **5.4: Conclusion**

This thesis has tested the validity of PHH and EKC hypothesis at the regional level of Asian countries (West Asia, Central Asia, East Asia, South Asia, and Southeast Asia). The thesis finds existence of PHH in East Asia while it does not in Southeast Asia. Hence, East Asian region should adopt cleaner technology production and the related environmental regulation to reduce its greenhouse gas emission. While examining the EKC hypothesis in these sub panels it was found that inverted U-shaped relationship exist between economic growth and environmental quality in Central and East Asian countries which validates the EKC hypothesis in these sub panels. Further, this thesis also examine the effect of trade on the environmental quality based on the income level of Asian countries (high income, upper middle and lower middle income countries). Decomposing the trade effect into scale, technique and composition effect the study analysed the consequence of trade at three distinct transition points for sample panels. The study found scale and technique effect to be statistically significant positive and negative impact on the EF respectively, while composition effect decreases them all the income group panels. Moreover, energy consumption found to be main determinants of environmental degradation in Asian countries.

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# Does foreign direct investment impede environmental quality in Asian countries? A panel data analysis

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## Abstract

This study aims to investigate the validity of the pollution haven hypothesis for the global panel consisting of 29 countries (are Bahrain, Israel, Jordan, Saudi Arabia, Turkey, United Arab Emirates, Oman, Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, Uzbekistan, China, Japan, Mongolia, Hong Kong, Korea rep, Bangladesh, India, Pakistan, Sri Lanka, Nepal, Iran, Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam are taken as the sample of this study.) with energy consumption, economic growth and trade openness as additional determinants of environmental degradation over the period 1994–2014. To make the panel data analysis more homogenous, we also investigate the validity of the PHH for a number of sub-panels. These sub-panels are constructed based on the sub-regions of Asia. In this way, we end up with five Asian panels; namely, Global panel, West Asia, Central Asia, East Asia, South Asia and Southeast Asian panels. Based on the IPS and ADF chi-square unit root test and Pedroni cointegration test results, all variables were found to be first difference stationary and cointegrated. On applying FMOLS, the long-run results suggest the presence of the pollution haven hypothesis only in East Asian panel. In turn, foreign direct investment reduces environmental degradation, thus rejecting the validity of the pollution haven hypothesis (PHH) in the Southeast Asian panel which is found to be negatively linked to CO<sub>2</sub> emissions. Moreover, energy consumption seems to be the main determinant of Carbon emissions and GDP growth has a positive impact on it in all panels except West Asia. Lastly, climate policies have benefited East Asian countries to reduce their carbon emissions by signing the Kyoto protocol.

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## 1. Introduction

Foreign direct investment (FDI) worldwide has grown markedly since the 1970s, reaching \$1.76 trillion in 2015. According to UNCTAD Annual Report (2016),

JEL classification: Q5, N55, F01, F3, F43, C23, P28.

developing Asia is now the largest recipient and accounts for almost one-third of total FDI inflows. The economic diversification had become a main economic and political priority in the Asian economies. This goal of economic diversification is initiated when the Asian countries started to encourage foreign investors and private sectors to increase their role in the Asian economies to accomplish more economic liberalisation. This new economic policy opened a wider range of activities to foreign direct investment (FDI), (World Investment Report, 2016) which helped in inclusive economic growth and integration by enhancing total factor productivity through technological and knowledge spillovers through physical and human capital accumulation which contributes directly to economic growth, thereby facilitating economic development for capital starved and technologically backwards developing countries. FDI inflows to developing Asia are expected to increase by 15 per cent in 2017, as an improved economic outlook in major Asian economies is likely to boost investor confidence in the region (World Investment Report, 2016) since they are moving towards more economic liberalisation. Presently, global FDI has become especially challenging; many investors are forced to hold their investments in the Middle East and the Asia Pacific. Moreover, by allowing economies to link to global and regional value chains, FDI potentially facilitates regional integration an export-oriented development strategy that many in Asia have followed successfully. Foreign direct investment is an important source of capital which can enhance technological transfer to the host countries and stimulate economic growth and development.

In general, FDI has the following three important effects on the host country economy: (i) (Bosworth *et al.*, 1999) filling the gap between targeted investment and domestic savings (ii) (Alfaro, 2003) boosting said country's development efforts (iii) (Bustos, 2007), offering itself as a source of external capital. Furthermore, FDI can also aid innovative learning may provide direct capital financing; generate positive externalities such as a mixture of technical skills which consequently stimulate economic growth, through technology transfer, productivity gains spillover effects and the introduction of new processes (Lee, 2013). Copeland and Taylor (1994), Cole (2004) finds that developing countries tend to undermine environmental concerns through relaxed or non-enforced regulation, which is termed as pollution haven hypothesis (PHH).

Rapid industrialisation has led to increasing environmental concerns, such that the links between foreign investment and environment pollution have been intensely debated. Some studies (e.g. Kirkulak *et al.*, 2011; Atici, 2012; Lan *et al.*, 2012) found that FDI inflows can reduce pollution by transferring environment friendly technologies from developed to less or weak developed countries, while some other studies (e.g. Cole and Elliott, 2005; Cole *et al.*, 2006; Wang *et al.*, 2013) found that FDI inflows have a positive effect on pollution. This positive relationship between FDI and carbon



emissions known as pollution heaven hypothesis which defines that the pollution intensive firms or industries are more likely to move from developed or advance countries to developing countries because the environmental regulation in these countries is weak or less stringent.

This branch of research on the relationship between FDI and economic growth in environmental sustainability remains debatable worldwide due to contradictory empirical results. There have been many studies conducted to examine the CO<sub>2</sub> determinants. Energy consumption and economic growth are two important determinants of CO<sub>2</sub> and research found that energy consumption and output have a significant positive effect on CO<sub>2</sub> emissions (Ang, 2007; Lotfalipour *et al.*, 2010; Menyah and Wolde-Rufael, 2010; Marrero, 2010; Pao and Tsai, 2010, 2011a,b; Hossain, 2011; Al-Mulali and Sab, 2012a; Arouri *et al.*, 2012; Hossain, 2012b; Wang *et al.*, 2013). However, some studies observed that the relationship between FDI and CO<sub>2</sub> emissions is negative for example: Romer (1986), Lucas (1988), Rebelo (1991), Romer (1993), Kirkulak *et al.* (2011), Atici (2012), Lan *et al.* (2012). On the other hand, some studies observed that the relationship between FDI and CO<sub>2</sub> emissions is positive, thus supporting the pollution haven hypothesis (e.g., Grimes and Kentor, 2003; Cole and Elliott, 2005; Cole *et al.*, 2006; Baek and Koo, 2009; Wang *et al.*, 2013).

To invest abroad, Japan is one of the countries that exert great efforts among the countries in the Asian region, mostly Southeast Asia region. Hitam and Borhan (2012) and Wang *et al.* (2013) found the positive relationship between FDI and CO<sub>2</sub> emissions in China and Malaysia. Using the generalised method of moment (GMM) estimator, He (2006) also arrived at the same conclusion that FDI has a positive effect on pollution via its impact on output growth in the Chinese provinces. Further exploring the pollution haven hypothesis and the environmental impact of FDI in 29 Chinese provinces' Cole *et al.* (2006) suggest that due to the low stringent environmental policies, less developed countries are always the best choice of investment. In one of the studies, Atici (2012) analyse the relationship between CO<sub>2</sub> emissions, exports, growth and the Japanese FDI to ASEAN countries and found that FDI has no impact on the CO<sub>2</sub> emissions in ASEAN countries whereas exports and growth have a significant positive effect on CO<sub>2</sub> emissions. To examine the impact of FDI and output on the environmental quality in 112 major cities in China, Cole *et al.* (2011) employed the panel data approach and found that FDI and economic growth have a statistically significant and positive effect on water and air pollutions in these major cities, supporting the pollution haven hypothesis in the Chinese economy.

The pollution haven hypothesis received considerable attention in developing countries (Cole, 2004; He 2006; Kearsley and Riddel 2010). Using data from the countries forming the Gulf Cooperation Council (GCC), Al-mulali and Tang (2013) investigated the validity of the PHH, by applying panel cointegration and causality

approaches. Their result suggested that CO<sub>2</sub> is increased by economic growth and energy consumption but lowered by FDI. Besides other, some related studies were conducted on developed and the Central and East European countries Waldkirch and Gopinath (2008), Jorgenson (2009), Lee (2009) in Malaysia and less developed countries and Mexico, also found that FDI has a positive effect on pollution, thus supporting the existence of pollution haven hypothesis, respectively.

It appears from the literature review which clearly shows FDI is the main activity which creates the pollution. However, it is hard to say the pollution haven hypothesis is certain. Moreover, none of the previous studies has investigated and compared the hypothesis in the six panels of Asian countries namely global, West, Central, East, South and Southeast Asia. Therefore, it is essential to empirically examine the validity of the pollution haven hypothesis in the Asian sub-region countries.

Foreign direct investment outflows from Japan and Taiwan to ASEAN countries like Malaysia, Indonesia, Thailand, Cambodia, from the European Union (EU) to the Eastern Europe and others. By sub-region, East Asia continues to be the primary destination, accounting for 60 per cent of all Asia bound global FDI and driven primarily by the PRC and Hong Kong. South Asia and Southeast Asia also posted a slight increase, with 9 per cent and 24 per cent, respectively, of the total inflows to the region (Asian Economic Integration Report, Asian Development bank (ADB); 2016). Japan is the dominant source of FDI in Asia, while the People's Republic of China (PRC) is the most popular host. East Asian economies such as the PRC, Japan and the Republic of Korea were among the top 10 Asian sources of global FDI and in Southeast Asia, Singapore and Malaysia (Asian Economic Integration Report, ADB; 2016). It is expected that the pollution haven hypothesis might take place in the sub-regions of Asian countries since FDI inflow is at an increasing rate. The main goal of this study is to examine whether FDI inflows have any significant impact on pollution in the six sub-region of Asian panel countries such as global panel, West Asia, Central Asia, East Asia, South Asia and Southeast Asian countries. These countries are highly polluted because the level of CO<sub>2</sub> emissions increased by more than 200 per cent (International Energy Agency, 2016). If the pollution haven hypothesis is valid, policymakers have to find ways to mitigate that; otherwise reducing FDI inflow may retard the economic growth of a country. Therefore, it is essential to examine the validity of the pollution haven hypothesis in the Asian sub-region countries. To examine the validity of the pollution haven hypothesis in the sub-region of Asian countries, panel unit root tests developed by Im *et al.* (2003) and xuehua and nini (2011) is used to investigate the order of integration using the Im-Pesaran-Shin (IPS) and ADF-Fisher. Secondly, to investigate the presence of a long-run equilibrium relationship between CO<sub>2</sub> emissions and its determinants, the panel cointegration proposed by Pedroni (1999), is implemented.

The next section will provide a brief theory of the Asian economies. The main interest of this study is to examine the validity of the pollution haven hypothesis. Therefore, special attention will be given to the relationship between FDI and CO<sub>2</sub> emissions in East and Southeast Asian countries because FDI inflow in these countries is highest among other Asian sub-panels. Section 3 will discuss the data source and descriptive statistics. Sections 4 methodologies and the conceptual framework and 5 will be devoted to empirical results and, lastly conclusions and policy implications

## 2. The Asian economies

Asia is the world's largest continent, comprises more than 4.4 billion people (60 per cent of the world Population),<sup>1</sup> and thus offers concentrations of cheap labour. Japan in addition to be a source country of FDI, is also the fastest growing economic region as well as the largest continental economy by both public-private partnership (PPP) and GDP Nominal in the world.<sup>2</sup> In the recent decade China and India are the first and third largest economies in Asia, respectively. Moreover, Asia is the site of some of the world's longest modern economic booms, starting from Japan, then in South Korea, Singapore, Hong Kong, Malaysia and Indonesia, among others.<sup>3</sup> In case of the west Asia countries namely Saudi Arabia Qatar, United Arab Emirates, Bahrain, Iran, Kuwait and Oman, prosperity has been largely due to these countries' vast reserves of oil and other forms of non-renewable energy, in particular, gas. China, India, Japan, South Korea, Indonesia, Turkey, Iran, Saudi Arabia and others countries of Asia are largest in terms of PPP Gross domestic product GDP (Barros *et al.* 2013). The good prospects for the Asian economies have ensured that FDI has continued to flow into these countries, despite financial crisis that rocked the Asian Pacific countries in 1997 (UNCTAD, the World Investment Report, 2003), and despite the many military conflicts and tensions that have plagued certain Asian regions and continue to destabilise others. However, Middle East depend more on engineering to overcome climate difficulties for economic growth and the production of commodities, whereas East Asian and Southeast Asian countries generally rely on manufacturing and trade.<sup>4</sup>

According to the statistics reported in the UNCTAD database, during the period from 1970 to 2011, the more advanced developing countries welcomed the main share, more than 90 per cent of total FDI Inflow, while the least developed Asian countries attracted the least amount of FDI, accounting for <1 per cent on average. But during the period from 2014 to 2015 the global FDI inflows increased 38 per cent and global FDI inflows to Asia by sub regions are 59.9, 3.0, 9.2, and 23.8 per cent for which East Asia accounting for highest FDI inflow followed by central Asia, South Asia and Southeast Asia, respectively, according to the (Asian Economic Integration Report, 2016). Furthermore, with the implementation of an open-door policy and the start of a program of structural reforms Hong Kong and China attracted large FDI volumes, to underscore

its importance as a hub for financial investment, with Singapore and India following. This also explains the large FDI flows between China, PRC and Hong Kong, (Asian Economic Integration Report, Asian development bank, 2016)

### 3. Data source and descriptive statistic

The present paper aims to analyse the impact of FDI on environmental degradation by incorporating energy consumption, economic growth and trade openness in the CO<sub>2</sub> function. A balanced panel data from 1994 to 2014 is used in this study. The annual data for CO<sub>2</sub> emissions (metric tons per capita), GDP per capita (constant 2010 US\$), trade (per cent of GDP), FDI (per cent of GDP) and Energy consumption (kg of oil equivalent per capita) are extracted from the World Bank's World Development Indicators database. All the variables are transformed into natural log form, in order to interpret the coefficient estimates as the elasticity's of the response variable (CO<sub>2</sub> emissions) with respect to the independent variables (Y and EC) except trade openness and FDI (as these variables are already expressed in percentage). GDP growth and Energy consumption is used in the CO<sub>2</sub> emission model because they were considered as major determinants of CO<sub>2</sub> emission by different studies, such as Ang (2007), Hossain (2011), Pao and Tsai (2011a,b), Al-Mulali and Sab (2012a; 2012b), which found linear relationships between the variables. The specific countries selected for the study and the timeframe was dictated by data availability and the need for a balanced panel, therefore the database is selected to get the maximum number of observations depending on the availability of data. These include sub regions of Asian countries: (i) West Asia consisting of seven countries (Bahrain, Israel, Jordan, Saudi Arabia, Turkey, United Arab Emirates and Oman); (ii) Central Asia consisting of five countries (Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan); (iii) East Asia consisting of five countries (China, Japan, Mongolia, Hong Kong and Korea Republic); (iv) South Asia consisting of six countries (Bangladesh, India, Pakistan, Sri Lanka, Nepal and Iran); (v) Southeast Asian panel consisting of six countries (Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam) are taken as the sample of this study.

**Table 1** presents the descriptive statistics for all the variables used in the study. The common summary statistics contains the mean, standard deviation and coefficient of variation of each series.

According to these statistics result, CO<sub>2</sub> emissions are measured in metric tons, and we find that the mean of CO<sub>2</sub> emissions is recorded highest for West Asian countries followed by East, Central, Global and Southeast Asian countries at 2.30, 1.84, 1.20, 1.20 and 0.94 metric tons per capita, respectively. We also note that global panel is most volatile in releasing CO<sub>2</sub> metric tons per capita; it has the highest coefficient of variation of 1.12, followed by Central, Southeast, West, East Asian countries. It implies that

**Table 1** Summary statistics by panel

| Panels         | Statistics               | CO <sub>2</sub> emissions<br>(metric tons per capita) | Energy consumption<br>(kg of oil Equivalent<br>per capita) | GDP per capita<br>(constant 2010 US\$) | Trade<br>(% GDP) | FDI inflow<br>(% GDP) |
|----------------|--------------------------|-------------------------------------------------------|------------------------------------------------------------|----------------------------------------|------------------|-----------------------|
| Global Panel   | Mean                     | 1.202                                                 | 7.290                                                      | 8.393                                  | 80.871           | 4.149                 |
|                | Std. deviation           | 1.356                                                 | 1.099                                                      | 1.459                                  | 71.636           | 6.055                 |
|                | Coefficient of variation | 1.127                                                 | 0.150                                                      | 0.173                                  | 0.885            | 1.459                 |
| West Asia      | Mean                     | 2.305                                                 | 8.206                                                      | 9.700                                  | 4.305            | 3.342                 |
|                | Std. deviation           | 0.793                                                 | 0.881                                                      | 0.832                                  | 0.415            | 4.415                 |
|                | Coefficient of variation | 0.344                                                 | 0.107                                                      | 0.085                                  | 0.096            | 1.321                 |
| Central Asia   | Mean                     | 1.2                                                   | 7.202                                                      | 7.328                                  | 4.316            | 5.013                 |
|                | Std. deviation           | 1.252                                                 | 0.996                                                      | 0.977                                  | 0.361            | 4.114                 |
|                | Coefficient of variation | 1.042                                                 | 0.138                                                      | 0.133                                  | 0.083            | 0.820                 |
| East Asia      | Mean                     | 1.840                                                 | 7.691                                                      | 9.227                                  | 104.414          | 6.893                 |
|                | Std. deviation           | 0.456                                                 | 0.570                                                      | 1.283                                  | 106.390          | 10.113                |
|                | Coefficient of variation | 0.247                                                 | 0.074                                                      | 0.139                                  | 1.018            | 1.467                 |
| South Asia     | Mean                     | -0.351                                                | 6.175                                                      | 7.098                                  | 37.426           | 0.907                 |
|                | Std. deviation           | 1.236                                                 | 0.795                                                      | 0.845                                  | 12.645           | 0.775                 |
|                | Coefficient of variation | -3.516                                                | 0.128                                                      | 0.119                                  | 0.337            | 0.854                 |
| Southeast Asia | Mean                     | 0.941                                                 | 7.077                                                      | 8.348                                  | 130.109          | 5.332                 |
|                | Std. deviation           | 0.966                                                 | 0.899                                                      | 1.196                                  | 80.890           | 5.993                 |
|                | Coefficient of variation | 1.025                                                 | 0.127                                                      | 0.143                                  | 0.621            | 1.124                 |

countries in the early stages of growth, such as those from the global and central Asian countries, pollute more.

Based on the aggregate energy consumption measured in kg of oil equivalent per capita, it can be seen that mean energy consumption is recorded highest for West Asia, followed by East, global panel, central and southeast Asia. It can also be seen that global panel are more volatile as it records the highest coefficient of variation.

A similar pattern exists for the per capita GDP, where the West Asian countries' average GDP per capita is recorded highest compared to East, global panel, Southeast, central and south Asian countries, respectively.

On average trade measured as a percentage of GDP, it can be noticed from the Table 1 that Southeast Asian countries are relatively more open to trade as compared with other Asian countries, whereas for West and Central Asia, their trade openness is almost same. Again it is a stylised fact in the literature of international trade which has documented that the countries with more liberalisation are more open to trade (see for example Harrigan, 1996; Chamon and Kremer 2009).

Finally, the mean foreign direct investment (FDI) inflow measured as a percentage of GDP is recorded highest in East Asia, followed by Southeast, Central, global panel, West and South Asian countries. FDI is used as a technology for the growth of the country but depending upon the type of FDI, if the validity of pollution haven hypothesis is found to be positive significant it is harmful to a country as it pollutes the environment and increases the CO<sub>2</sub> emissions.

In sum, the summary statistic reveals that the West Asian countries have greater energy consumption, economic growth whereas Southeast Asia is more open to trade followed by other Asian countries panel. These are not surprising findings, our classification of countries into sub-panels based on Asian countries level is crucial in terms of homogenising countries into similar characteristics. It gives a clear distinction amongst the four types of countries based on summary statistics by panel of the four variables. This will ensure that a particular Asian classified country will not be dictating the results and clear comparison of the effect of energy consumption, economic growth, trade openness and FDI inflow on carbon dioxide emissions can be undertaken for panel country at different stages of development.

#### 4. Empirical model and methodology

The following is the form of our proposed model

$$\text{CO}_2 = f(\text{EC}, Y, \text{FDI}, \text{TO}) \quad (1)$$

Equation (1) states that energy consumption (EC), economics growth (Y), Trade openness (TO) and foreign direct investment (FDI) can potentially determine CO<sub>2</sub>



emissions. There are a number of studies (Ang 2007; Hossain 2011; Pao and Tsai 2011a, b), that found a linear relationship between energy consumption, economic growth and CO<sub>2</sub> because they were considered as main determinant of CO<sub>2</sub> emissions. However there were some studies such as Wang (2012); Esteve and Tamarit (2012) that found a non-linear relationship between economic growth, energy consumption and CO<sub>2</sub> emissions. FDI is used in this study as a determinant of CO<sub>2</sub> emission which is in line with previous studies (for example Pao and Tsai, 2011b; and Al-mulali, 2012) that utilised it as a major determinant of pollution in their CO<sub>2</sub> emission models. Following this argument, to analyse the relationship between carbon dioxide and its determinants for subregions of Asian panel countries, we write Equation (1) in panel model form as follows:

$$CO_{2it} = \pi_0 + \pi_1 EC_{it} + \pi_2 Y_{it} + \pi_3 FDI_{it} + \pi_4 TO_{it} + \pi_5 DV + \mu_{it} \quad (2)$$

where  $\pi$ 's represent the regression coefficient;  $i$  represents country (in our study, we have 25 countries);  $t$  represents time (our time frame is 1994–2014);  $CO_{2it}$  is the natural log carbon emissions (metric tons per capita);  $EC_{it}$  is the log of the per capita energy consumption (kg of oil equivalent per capita);  $Y_{it}$  is the per capita real GDP measured in constant 2010 US\$;  $FDI_{it}$  is foreign direct investment inflow as a percentage of GDP;  $TO_{it}$  represents the trade openness, measured as exports plus imports as percentage of GDP. The long-run parameters for CO<sub>2</sub> emissions with respect to energy consumption, per capita GDP, FDI and trade openness are  $\pi_1$ ,  $\pi_2$ ,  $\pi_3$  and  $\pi_4$ . The expected sign for  $\pi_1$  &  $\pi_2$  is positive while  $\pi_3$  and  $\pi_4$  can be either positive or negative. DV is dummy variables; we have created dummy variables (dummy) to capture the effect of international and national policy changes that have been made in 1997 on CO<sub>2</sub> emissions. Here, Dummy = 0, when there is no changes in climate policy while Dummy = 1, when changes in climate policy. If the dummy variables are found significant and positive then climate policy adopted national and internationally has a positive effect on CO<sub>2</sub> emissions otherwise climate policy will reduce carbon emissions in Asian countries, therefore coefficient  $\pi_5$  may be positive or negative depending on the countries adoption of climate policy.

#### 4.1. Panel unit root tests

We propose two kinds of panel unit root tests (ADF fisher and Im *et al.*, 2003, IPS) to test the stationary properties of panel data. These tests allow individual unit root processes autoregressive coefficients to vary across cross-sections. The Im–Pesaran–Shin (IPS) and ADF-fisher tests assume an individual unit root process across the cross-section for the null of a unit root to obtain panel results. The application of these unit root tests is essential in identifying the order of integration of the variables, therefore it is an

important issue to be considered as it determines the selection of the models for empirical analysis. The null hypothesis for this test can be shown as  $H_0: \rho_i = 1$  whereas alternate hypothesis as  $H_1: \rho_i < 1$  which means variables contains and does not contain panel unit root, respectively. For instance, all the variables are non-stationary at levels and stationary at their first-order differentials, if all of the variables are integrated in the order of 1 or I (1).

#### 4.2. Panel Cointegration test

We employ panel cointegration techniques to examine the existence of a long-run relationship between CO<sub>2</sub> emissions, energy consumption, economics growth, FDI and trade in the sub-regions of Asian countries.

In this study, we apply the residuals-based test for cointegration methodology which is proposed and developed by Pedroni (1999, 2004). Pedroni (2004) proposes seven statistics distributed on two sets of cointegration tests that allow for heterogeneity in the intercepts and trend coefficients across countries. In time series analysis, similar residuals-based test for cointegration is proposed by Engle and Granger (1987). To implement Pedroni's cointegration test, Pedroni (1999) utilises the two-step regression framework to test for panel cointegration. Therefore we firstly estimate the following panel regression model and save the residuals:

$$y_{i,t} = \gamma_i + \sigma_i t + \beta_{1i} Z_{1i,t} + \beta_{2i} Z_{2i,t} \dots \dots \dots \beta_{mi} Z_{mi,t} + \mu_{i,t} \quad (3)$$

Here  $y_{i,t}$  are the dependent variables, while  $Z_{1i,t}$  are the independent variables assumed to be integrated of order I (1);  $\mu_{i,t}$  are the residuals derived from the above panel regression;  $\gamma_i$  and  $\beta_{1i}, \beta_{2i}, \dots, \beta_{mi}$  are the intercept term and slope coefficient that vary across every individual member of the panel, respectively. To test whether or not the residuals are stationary, we present the following panel regression model with the saved residuals. Under the null hypothesis of no cointegration, the residuals are stationary, I (0) or not. The estimated residuals are defined as follows:

$$\Delta \mu_{i,t} = \delta_i \mu_{i,t-1} + \varepsilon_{i,t} \quad (4)$$

$$\Delta \mu_{i,t} = \delta_i \mu_{i,t-1} + \sum_{j=1}^{\delta_i} \theta_{ij} \mu_{i,t-j} + \omega_{i,t} \quad (5)$$

Here  $\mu_{i,t}$  are the residuals extracted from Equation (1);  $\Delta$  is the first difference operator. The residuals  $\varepsilon_{i,t}$  and  $\omega_{i,t}$  are assumed to be normally distributed and white noise. Pedroni (2004) suggested different statistics to examine the null hypothesis of no cointegration. First four tests are panel v statistic, panel rho-statistic, PP statistic and ADF statistic. Moreover, these statistics are classified on within dimension and take into



account common autoregressive coefficient across countries. The second group of test includes group rho-statistic, group PP statistic and group ADF statistic. Based on the individual autoregressive coefficients for each country in the panel, these tests are classified on the between-dimension.

### 4.3. Fully modified OLS estimates

An important inference of an empirical study is to estimate the long-run coefficients of the explanatory variables after we find that carbon emissions, energy consumption, the real income, FDI, trade openness are cointegrated. The OLS estimators of the cointegrated vectors are super-convergent and commonly used ones in a variety of literature. However, the dynamic ordinary least squares (DOLS) and the fully modified ordinary least squares (FMOLS) estimators have been recently preferred to the OLS estimator (Lee, 2007). To examine the long-run elasticities for each explanatory variable, we employ the group mean Fully Modified OLS (FMOLS) estimator. FMOLS that was initially suggested by (Philips and Hansen; 1990), is more powerful than the OLS because it corrects for both endogeneity bias and serial correlation. One of the advantages of using FMOLS is that long-run correlation problem gets eliminated. Phillips and Moon (1999) showed that the FMOLS estimator appears to outperform both estimators while the OLS technique exhibits small sample bias. It is unbiased. Kao and Chiang (2001) also showed that FMOLS techniques led to normally distributed estimators. Using asymptotic Chi-square statistical inference, it has full asymptotic efficiency allowing for standard Wald tests.

## 5. Empirical Results

### 5.1. Panel unit root test results

Prior to testing cointegration, two panel unit root tests such as Im–Pesaran–Shin (IPS) and Augmented Dickey fuller (ADF) fisher are applied at level and first difference to check the integrated properties of the variables. The results of the unit root test are summarised in **Tables 2–7** for the six different sub-regions of Asian panel namely (the global panel, West Asia, Central Asia, East Asia, South Asia and Southeast Asia panel). In all the six panels it can be seen that foreign direct investment is stationary in its level form. The Im–Pesaran–Shin (IPS) results show that all the variables are stationary at the first difference. Likewise, the ADF-Fisher tests also show that variables are non-stationary in levels and stationary at first difference, as we reject the null hypothesis at the 1 per cent significance level implying that CO<sub>2</sub> emissions, Energy consumption, GDP per capita, FDI and trade openness belong to I (1) process. Based on these results, all the selected variables (lnCO<sub>2</sub>, lnEC, lnY, FDI and TO) are stationary at first

**Table 2** Panel unit root analysis for global panel

| Variables          | at level   |                   | at 1st difference |                   |
|--------------------|------------|-------------------|-------------------|-------------------|
|                    | Intercept  | Intercept & trend | Intercept         | Intercept & trend |
| IPS unit root test |            |                   |                   |                   |
| CO <sub>2</sub>    | −0.384     | 0.169             | −13.606***        | −14.198***        |
| EC                 | 1.312      | −2.726***         | −15.344***        | −13.178***        |
| GDP                | 6.416      | −0.733            | −9.966***         | −8.344***         |
| TR                 | 0.154      | −3.335***         | −17.734***        | −14.863***        |
| FDI                | −5.628***  | −7.747***         | −19.768***        | −15.367***        |
| ADF unit root test |            |                   |                   |                   |
| CO <sub>2</sub>    | 70.966     | 62.230            | 292.578***        | 276.056***        |
| EC                 | 59.438     | 99.498***         | 316.082***        | 257.136***        |
| GDP                | 37.518     | 64.310            | 210.483***        | 172.633***        |
| TR                 | 63.386     | 95.105***         | 364.856***        | 285.920***        |
| FDI                | 135.849*** | 161.634***        | 409.158***        | 296.107***        |

The unit root tests were done with individual trends and intercept for each variable lag length were selected automatically using the Schwarz Information Criteria (SIC).

\*, \*\*, \*\*\*Statistical significance at the 10, 5 and 1 per cent levels.

**Table 3** Panel unit root analysis for West Asia

| Variables          | at level  |                   | at 1 <sup>st</sup> difference |                   |
|--------------------|-----------|-------------------|-------------------------------|-------------------|
|                    | Intercept | Intercept & trend | Intercept                     | Intercept & trend |
| IPS unit root test |           |                   |                               |                   |
| CO <sub>2</sub>    | −1.668**  | 0.166             | −8.395***                     | −8.191***         |
| EC                 | 0.629     | −1.174            | −7.709***                     | −6.557***         |
| GDP                | 0.628     | −0.049            | −4.079***                     | −2.614***         |
| TR                 | 1.380     | −1.101            | −7.598***                     | −6.322***         |
| FDI                | −2.364*** | −2.919***         | −8.610***                     | −6.264***         |
| ADF unit root test |           |                   |                               |                   |
| CO <sub>2</sub>    | 21.734*   | 13.363            | 86.494***                     | 77.228***         |
| EC                 | 11.463    | 19.186            | 78.775***                     | 62.619***         |
| GDP                | 10.589    | 11.599            | 43.302***                     | 30.908***         |
| TR                 | 10.167    | 21.103*           | 76.513***                     | 59.289***         |
| FDI                | 26.911**  | 32.503***         | 85.403***                     | 59.573***         |

The unit root tests were done with individual trends and intercept for each variable lag length were selected automatically using the Schwarz Information Criteria (SIC).

\*, \*\*, \*\*\*Statistical significance at the 10, 5 and 1 per cent levels.

**Table 4** Panel unit root analysis for Central Asia

| Variables          | at level  |                   | at 1st difference |                   |
|--------------------|-----------|-------------------|-------------------|-------------------|
|                    | Intercept | Intercept & trend | Intercept         | Intercept & trend |
| IPS unit root test |           |                   |                   |                   |
| CO <sub>2</sub>    | 0.616     | −0.527            | −3.596***         | −3.988***         |
| EC                 | 1.084     | −0.285            | −5.437***         | −6.063***         |
| GDP                | 2.359     | −1.237            | −5.318***         | −3.184***         |
| TR                 | −0.771    | −1.478*           | −6.578***         | −5.214***         |
| FDI                | −3.060*** | −2.546***         | −12.348***        | −9.076***         |
| ADF unit root test |           |                   |                   |                   |
| CO <sub>2</sub>    | 10.061    | 10.636            | 34.742***         | 34.488***         |
| EC                 | 5.018     | 11.518            | 45.667***         | 46.557***         |
| GDP                | 5.342     | 17.974*           | 45.299***         | 27.633***         |
| TR                 | 12.633    | 17.349*           | 55.544***         | 41.873***         |
| FDI                | 26.083*** | 21.415**          | 105.866***        | 70.830***         |

The unit root tests were done with individual trends and intercept for each variable lag length were selected automatically using the Schwarz Information Criteria (SIC).

\*, \*\*, \*\*\*Statistical significance at the 10, 5 and 1 per cent levels.

**Table 5** Panel unit root analysis for East Asia

| Variables          | at level  |                   | at 1st difference |                   |
|--------------------|-----------|-------------------|-------------------|-------------------|
|                    | Intercept | Intercept & trend | Intercept         | Intercept & trend |
| IPS unit root test |           |                   |                   |                   |
| CO <sub>2</sub>    | 0.562     | −0.497            | −3.389***         | −5.192***         |
| EC                 | −0.261    | −4.314***         | −5.721***         | −4.188***         |
| GDP                | 0.872     | −0.559            | −4.873***         | −4.535***         |
| TR                 | −0.09     | −0.372            | −7.367***         | −6.698***         |
| FDI                | −0.903    | −4.768***         | −6.547***         | −5.439***         |
| ADF unit root test |           |                   |                   |                   |
| CO <sub>2</sub>    | 10.542    | 20.199**          | 35.864***         | 43.612***         |
| EC                 | 19.102**  | 36.201***         | 49.094***         | 36.410***         |
| GDP                | 19.883    | 11.711            | 42.122***         | 38.072***         |
| TR                 | 10.793    | 11.311            | 62.150***         | 51.892***         |
| FDI                | 18.808**  | 39.118***         | 56.909***         | 44.412***         |

The unit root tests were done with individual trends and intercept for each variable lag length were selected automatically using the Schwarz Information Criteria (SIC).

\*, \*\*, \*\*\*Statistical significance at the 10, 5 and 1 per cent levels.

**Table 6** Panel unit root analysis for South Asian countries

| Variables          | at level  |                   | at 1st difference |                   |
|--------------------|-----------|-------------------|-------------------|-------------------|
|                    | Intercept | Intercept & trend | Intercept         | Intercept & trend |
| IPS unit root test |           |                   |                   |                   |
| CO <sub>2</sub>    | 0.574     | 1.571             | −7.674***         | −7.366***         |
| EC                 | 2.984     | 0.777             | −8.649***         | −8.338***         |
| GDP                | 5.838     | 0.462             | −2.887***         | −3.152***         |
| TR                 | −1.419*   | −2.570***         | −10.685***        | −8.726***         |
| FDI                | −2.150**  | −1.719**          | −7.907***         | −6.220***         |
| ADF unit root test |           |                   |                   |                   |
| CO <sub>2</sub>    | 15.549    | 5.412             | 70.597***         | 63.020***         |
| EC                 | 5.59      | 9.419             | 79.632***         | 70.268***         |
| GDP                | 0.824     | 9.564             | 30.086***         | 30.049***         |
| TR                 | 22.737**  | 24.547**          | 99.367***         | 74.796***         |
| FDI                | 23.602**  | 20.769*           | 73.757***         | 54.276***         |

The unit root tests were done with individual trends and intercept for each variable lag length were selected automatically using the Schwarz Information Criteria (SIC).

\*, \*\*, \*\*\*Statistical significance at the 10, 5 and 1 per cent levels.

**Table 7** Panel unit root analysis for Southeast Asian countries

| Variables          | at level  |                   | at 1st difference |                   |
|--------------------|-----------|-------------------|-------------------|-------------------|
|                    | Intercept | Intercept & trend | Intercept         | Intercept & trend |
| IPS unit root test |           |                   |                   |                   |
| CO <sub>2</sub>    | −0.748    | −0.306            | −7.007***         | −6.647***         |
| EC                 | −1.383*   | −1.091            | −6.607***         | −4.299***         |
| GDP                | 4.719     | −0.332            | −5.341***         | −5.242***         |
| TR                 | 0.943     | −1.845**          | −7.526***         | −6.418***         |
| FDI                | −4.157*** | −5.318***         | −9.185***         | −7.558***         |
| ADF unit root test |           |                   |                   |                   |
| CO <sub>2</sub>    | 13.079    | 12.618            | 64.879***         | 57.705***         |
| EC                 | 18.264    | 23.173**          | 62.912***         | 41.280***         |
| GDP                | 0.878     | 13.460            | 49.672***         | 45.993***         |
| TR                 | 7.307     | 21.126**          | 72.276***         | 62.453***         |
| FDI                | 40.444*** | 47.827***         | 87.222***         | 67.014***         |

The unit root tests were done with individual trends and intercept for each variable lag length were selected automatically using the Schwarz Information Criteria (SIC).

\*, \*\*, \*\*\*Statistical significance at the 10, 5 and 1 per cent levels.

difference. Thus, using the Pedroni cointegration test, we can proceed to examine the existence of cointegration.

### 5.2. Panel cointegration test results

The results of the Pedroni (1999, 2004) cointegration tests for global panel are displayed in **Table 8** show that the null hypothesis of no cointegration can be rejected in most cases.

Specifically, four out of seven statistic tests reject the null hypothesis of no cointegration at the 1 per cent level. Similarly, we found the result for other panel groups such as West, Central, East, South and Southeast Asian panel which is presented in **Table 9**.

The result shows that the null hypothesis for no cointegration can be rejected in four out of seven statistics.

Therefore, carbon emissions, energy consumption, economic growth, FDI and Trade openness are cointegrated. By using the group mean panel Fully Modified OLS (FMOLS), we estimate the long-run coefficients of CO<sub>2</sub> emissions and its determinants. The results of FMOLS are reported in **Tables 10** and **11**.

### 5.3. Fully Modified OLS estimate results

The FMOLS results of the global panel are presented in Table 10 reveals that consumption of energy and per capita GDP positively and significantly affects CO<sub>2</sub>. This implies that 1 per cent increase in energy consumption and economics growth increases environmental emissions by 0.98 per cent and 0.14 per cent, respectively. This results was consistent with the outcome of a number of previous studies that also found a long

**Table 8** Pedroni panel cointegration test result

| Models                     | Global Panel |                |
|----------------------------|--------------|----------------|
|                            | Statistic    | <i>P</i> value |
| Panel <i>v</i> Statistic   | −1.578       | 0.942          |
| Panel <i>rho</i> Statistic | 1.235        | 0.891          |
| Panel PP Statistic         | −4.419       | 0.000          |
| Panel ADF Statistic        | −5.465       | 0.000          |
| Group <i>rho</i> Statistic | 3.299        | 0.999          |
| Group PP-Statistic         | −7.839       | 0.000          |
| Group ADF-Statistic        | −7.488       | 0.000          |

Lag length and bandwidth are selected by Schwarz Information Criterion (SIC) and the Bartlett kernel Newey-West estimator.

**Table 9** Pedroni panel cointegration test result (sub regional countries)

| Sub Panels<br>Tests | West Asia  |          | Central Asia |          | East Asia  |          | South Asia |          | Southeast Asia |          |
|---------------------|------------|----------|--------------|----------|------------|----------|------------|----------|----------------|----------|
|                     | Statistics | P values | Statistics   | P values | Statistics | P values | Statistics | P values | Statistics     | P values |
| P. v-Stats          | -1.969     | 0.975    | 1.625        | 0.052    | -1.456     | 0.927    | -0.862     | 0.805    | -1.075         | 0.858    |
| P. rho Stats        | 1.878      | 0.969    | -0.144       | 0.442    | 0.362      | 0.641    | 1.153      | 0.875    | 0.604          | 0.727    |
| P.PP Stats          | -2.099     | 0.017    | -1.444       | 0.074    | -2.316     | 0.010    | -2.049     | 0.020    | -7.163         | 0.000    |
| P.ADF stats         | -2.703     | 0.003    | -1.351       | 0.088    | -2.331     | 0.009    | -1.983     | 0.023    | -6.425         | 0.000    |
| G. rho-Stats        | 2.801      | 0.997    | 0.578        | 0.718    | 2.216      | 0.986    | 2.129      | 0.983    | 1.809          | 0.964    |
| G.PP-Stats          | -1.550     | 0.060    | -4.328       | 0.000    | -4.132     | 0.000    | -2.381     | 0.008    | -4.802         | 0.000    |
| G. ADF stats        | -1.613     | 0.053    | -3.577       | 0.000    | -3.680     | 0.000    | -1.878     | 0.030    | -6.742         | 0.000    |

Lag length and bandwidth are selected by Schwarz Information Criterion (SIC) and the Bartlett kernel Newey-West estimator. Where P is Panel, G is Group & Stats is statistic.

**Table 10** Results for the Global Panel FMOLS

| Dependent Variable: CO <sub>2</sub> emissions | Coefficient | <i>P</i> value |
|-----------------------------------------------|-------------|----------------|
| Energy consumption                            | 0.981       | 0.000          |
| Dummy                                         | 0.013       | 0.617          |
| GDP per capita                                | 0.149       | 0.002          |
| Trade openness                                | −0.000      | 0.255          |
| FDI                                           | 0.000       | 0.689          |

relationship between CO<sub>2</sub> emission and its main determinants such as Tamazian and Rao (2010), Linh and Lin (2014), and Tang and Tan (2015) who suggested energy consumption and economic growth significantly contributed to CO<sub>2</sub> emissions. Trade openness and FDI has a statistically insignificant but has negative and positive impact on the CO<sub>2</sub> emissions, respectively.

We report the FMOLS result for Asian panel sub-regions countries in Table 11. In the West Asian panel, the elasticity of CO<sub>2</sub> emissions with respect to energy consumption is 0.87. This implies that increases in energy consumption increases carbon emissions in the West Asian panel. These results were similar to what was found by Halicioglu (2009), Al-mulali (2012), Al-mulali and Sheau-Ting (2014), and Kasman and Duman (2015). However, other scholars found a negative relationship between the two variables such as Hossain (2011), Jayanthakumaran *et al.*(2012), Kohler (2013), Shahbaz *et al.* (2013a,b), Sulaiman *et al.* (2013), Farhani and Shahbaz (2014), Dogan and Turkekul (2016), and Jebli *et al.* (2016). Also, trade openness and FDI are found to have statistically insignificant but positive effects on CO<sub>2</sub> emissions whereas per capita GDP was observed to have negative impact on carbon emissions.

In the Central Asian panel, similar results were found that economic growth and energy consumption has statistically significant positive effect on CO<sub>2</sub> emissions at 1 per cent level of significance. Thus imply that a 1 per cent increase in energy consumption and economic growth increases environmental pollution by 0.83 per cent and 0.09 per cent, respectively. These results are in consistence with the findings of Linh and Lin (2014), Al-Mulali *et al.* (2015), Al-Mulali and Ozturk (2016), Bento and Moutinho (2016). However, the increase in trade has a negative relationship and significantly effects CO<sub>2</sub> emissions. Some studies have also reached the same conclusion, but other studies found that the relationship between the two variables was positive or insignificant.

In the East Asian panel, the results for the long-run relationship between FDI by source and CO<sub>2</sub> emissions, increase in FDI inflow stimulate the level of emissions. The sign of the FDI coefficient is positive and statistically significant at 1 per cent level.

**Table 11** Results of FMOLS

| Sub regions               | West Asia   |         | Central Asia |         | East Asia   |         | South Asia  |         | Southeast Asia |         |
|---------------------------|-------------|---------|--------------|---------|-------------|---------|-------------|---------|----------------|---------|
| Dependent Variable:       | Coefficient | P value | Coefficient  | P value | Coefficient | P value | Coefficient | P value | Coefficient    | P value |
| CO <sub>2</sub> emissions |             |         |              |         |             |         |             |         |                |         |
| Energy consumption        | 0.871       | 0.000   | 0.837        | 0.000   | 0.553       | 0.003   | 0.768       | 0.001   | 1.132          | 0.000   |
| Dummy                     | 0.025       | 0.530   | 0.014        | 0.5831  | -0.076      | 0.068   | 0.041       | 0.455   | -0.051         | 0.486   |
| GDP per capita            | -0.103      | 0.391   | 0.093        | 0.0038  | 0.447       | 0.001   | 0.525       | 0.000   | 0.303          | 0.057   |
| Trade openness            | 0.000       | 0.374   | -0.000       | 0.0509  | -0.001      | 0.001   | -0.000      | 0.718   | -0.002         | 0.025   |
| FDI                       | 0.000       | 0.954   | -0.002       | 0.3607  | 0.010       | 0.000   | 0.006       | 0.808   | -0.028         | 0.000   |



Thus, CO<sub>2</sub> emissions increase by 0.01 per cent globally for every 1 per cent increase in FDI, which supports the pollution haven hypothesis (PHH). The implication is that foreign investors use worse management practices and shift dirty goods in the host countries resulting in increasing the level of environmental pollution in the host countries. This increase in carbon emissions, which also implies that higher the FDI inflow, higher will be the pollution since FDI inflow in East Asia is 60 per cent according to Asian Economic Integration Report (2016). Similar results were reported in Kiviyiro and Arminen (2015) which suggested that FDI increases CO<sub>2</sub> emissions in sub-Saharan Africa because of the low-quality technology used in production and the related environmental regulations. Shahbaz *et al.* (2015) and Jiang (2015) also showed that FDI deteriorates the environmental quality by increasing CO<sub>2</sub> emissions in 110 developed & developing countries and China, respectively. By contrast, Tamazian and Rao (2010) showed that FDI decreases CO<sub>2</sub> emissions in the case of 24 transition economies.

Furthermore, consumption of energy and per capita GDP increases pollution by its positive effect on CO<sub>2</sub> emissions in the long run. The increase in energy consumption and economic growth by 1 per cent will increase CO<sub>2</sub> emissions by 0.55 and 0.44 per cent, respectively. We can also observe that dummy variables which take into account the policy changes that have been made during 1994–2014 show that implementation of policy at a national and international level were able to reduce CO<sub>2</sub> emissions in East Asian countries which has a negative effect on carbon emissions. Meaning there by that a 1 per cent change in policy level reduces CO<sub>2</sub> emissions by 0.07 per cent, similarly trade also show a negative sign indicating a decrease in CO<sub>2</sub> emissions in East Asia.

Similar results were found in South Asia that energy consumption and per capita GDP has a statistically significant positive effect on CO<sub>2</sub> emissions at 1 per cent level of significance. It implies that a 1 per cent increase in energy consumption and economic growth increases environmental pollution by 0.76 and 0.52 per cent, respectively

Lastly in the Southeast Asian panel, the relationship between FDI and carbon emissions is found to be statistically significant and negatively related. FDI is negatively linked to CO<sub>2</sub> emissions and statistically significant at 1 per cent level significance. Thus, CO<sub>2</sub> emissions decline by 0.02 per cent globally for every 1 per cent increase in FDI. Since the FDI inflow in these countries is 24 per cent lower than East Asia which is almost 60 per cent, therefore we can conclude that lower the FDI, least will be the pollution. This finding is consistent with the Grimes and Kentor (2003) for the less developed economy thereby means that the foreign investor export pollution-free technology to the host country, resulting in pollution-free environment. In one of the studies, Chandran and Tang (2013) have investigated the effect of FDI on CO<sub>2</sub> emissions over the period 1971–2008 for ASEAN-5 economies using cointegration and Granger test. Their result found that FDI is not significant. Moreover, energy consumption stimulates the level of carbon emissions, unlike the earlier Asian panels. It is also seen

that economic growth has a statistically significant positive impact on CO<sub>2</sub> emissions while trade openness has a statistically significant negative impact on CO<sub>2</sub> emissions. Therefore energy consumption is an important contributor to environmental pollution in all the panels.

Summarizing the above results, the main findings are as follows. Firstly, our results show that energy consumption is positive and statistically significant at 1 per cent level of significance in all the six panels' namely global Asia, West Asia, Central Asia, East Asia, South Asia and Southeast Asian panel. It means energy consumption is an important determinant of carbon emissions in all the panels.

Secondly, per capita GDP is found to have a statistically significant effect on the CO<sub>2</sub> emissions except for West Asian panel. However, it has a positive effect on CO<sub>2</sub> emissions.

Thirdly trade of goods and services has a statistically insignificant impact on CO<sub>2</sub> emissions, meaning that trade openness is not a significant determinant of CO<sub>2</sub> emissions in global Asia, West Asia and South Asian panels. However, in the Central, East and Southeast Asian panel there is a statistically significant negative relationship between trade openness and CO<sub>2</sub> emissions. This result is inconsistent with the line of Heckscher-Ohlin trade theory which predicts greater opportunity of production and consumption of goods and services leading to greater environmental pollution.

Fourthly and lastly, we have found that the impact of foreign direct investment (FDI) on the two panels such as East and Southeast Asia panel are statistically significant with positive and negative effect on CO<sub>2</sub> emissions, respectively. Whereas in West and South Asia it is a positive but statistically insignificant relationship between FDI and carbon emissions while in the Central panel it shows negative relation. Therefore our empirical results reject the pollution haven hypothesis in the Southeast Asian panel countries whereas it accepts the validity of the pollution haven hypothesis in East Asian countries.

## 6. Conclusion and policy implications

The purpose of this study is to examine the existence of pollution haven hypothesis for the global panel consisting of 29 countries and for five sub-regional countries of Asian based panels (namely West Asia, Central Asia, East Asia, South Asia and Southeast Asia) throughout 1994–2014. Before testing for any causal relationship among the variables, panel unit root tests and panel cointegration tests are applied. To achieve the goal of this study, two different panel unit root tests of ADF chi square (fisher 1979) and IPS (Im *et al.*, 2003) have been used. The empirical evidence reveals that all the variables are integrated of order one or I (1). Also panel cointegration tests (Pedroni, 1999, 2004) have also been used. The outcome from the Pedroni cointegration confirmed the long-run relationship between CO<sub>2</sub> emissions, energy consumption, economic

growth, foreign direct investment (FDI) and trade openness. Moreover, the group means FMOLS results revealed that energy consumption and per capita GDP are two of the main determinants of CO<sub>2</sub> in the global panel. While the other variables namely trade openness have statistically insignificant effects on CO<sub>2</sub> emissions in global, West and South panels whereas foreign direct investment (FDI) has statistically insignificant impact on CO<sub>2</sub> emissions in global, West, Central and South Asia. It is also noted that per capita GDP has a statistically significant positive impact on CO<sub>2</sub> emissions for the all the panels, but it is statistically insignificant in the West Asia though it has negative effect on CO<sub>2</sub> emissions.

Furthermore, trade openness has a statistical insignificant impact on CO<sub>2</sub> emissions in West and South Asian panels though it is positive and negative, respectively. In addition, trade openness only has a statistically significant positive effect in the Central, East and Southeast Asia; this strongly illustrates that trade of goods and services is good for these countries to reduce CO<sub>2</sub> emission.

Finally, foreign direct investment (FDI) is found to have positive and negative effect on CO<sub>2</sub> emissions in East and Southeast Asian panels, respectively. FDI reduces CO<sub>2</sub> emissions at every stage of economic growth in Southeast Asian countries, but not in East Asia. This implies that FDI policies in East Asia effect environment pollution, in turn lowering environment quality. Increased FDI mainly in the industrial and production sectors in East Asian countries will result in significant environmental degradation and unsustainability over time due to pollution. This finding is consistent with Tamazian and Rao (2010) who found that increased FDI reduces CO<sub>2</sub> emissions. List and Co (2000) and Tamazian *et al.* (2009) suggest that by promoting technological innovation, sometimes FDI and economic growth can increase energy efficiency with low CO<sub>2</sub> emissions. The result for the global, West, Central and South Asia panel is inconclusive as foreign direct investment (FDI) has a statistically insignificant positive impact on CO<sub>2</sub> emissions in global, West and South Asia while the foreign direct investment (FDI) has a statistically insignificant negative impact on the CO<sub>2</sub> emissions in Central Asia.

From these findings, appropriate policies have been recommended for West-, Central-, East-, South- and Southeast Asian countries to exploit FDI and control pollution. Firstly, we find that GDP per capita of global, Central, East, South and Southeast Asian countries lead to more carbon dioxide emissions. To reduce emissions, these countries need to embrace more energy conservation policies. The second implication derived from our findings on the impact of energy consumption is that energy consumption positively and significantly contributes to carbon emissions in all the panels of Asian countries. With its 4.3 billion inhabitants accounting for 60 per cent of the world population, Asia is the most populous continent. This means they will exert more pressure on the environment, as population and industrial output in these countries expand, leading to more emissions. Here two points can be noted one there should be a

proper check on population control or policymakers should enhance the use of alternative source of energy. Thirdly, FDI impedes the environment quality in East Asian countries. As foreign direct investment (FDI) particularly increases pollution, more environmental preservation efforts are needed in East Asia. These countries should encourage the use of environment-friendly technologies to enhance domestic production. The governing bodies should also stop licensing polluting industries such as chemical and pharmaceutical firms and foundries, which emit more CO<sub>2</sub> emissions comparatively. Therefore these polluting firms must be regularly assessed for their environmental impact. In addition, increasing public awareness on the effect of hazardous waste and polluting industries as well as on preserving the environment. Firms must also be up to date using energy-saving technologies. Fourthly, the climate policy that has been signed (Kyoto protocol) show that only East Asian countries were able to reduce carbon emissions up to certain extent. Fifthly, these countries should utilise policies to encourage inward FDI especially on the services sector rather in polluting firms since it plays an important role in stimulating GDP growth and policies that regulate the FDI-environment relationships and reduce environmental pollution should be enforced in East Asian countries. The validity of Pollution Haven hypothesis is proven for East Asian panel.

Finally, FDI improves the environmental quality in Southeast Asian countries. Hence the pollution haven hypothesis in the case of Southeast Asian countries is invalid. It shows that developed or Southeast Asian countries could transfer their environment-friendly technologies to developing countries for protecting the environment from degradation. That will increase the environmental quality at the global level and protect environment quality in developing countries.

## Notes

1. Population of Asia in 2014" World population statistics.
2. <http://www.imf.org/external/datamapper/NGDPD@WEO/OEMDC/ADVEC/WEOWORLD>.
3. Due to their rapid development and industrialisation in the 1980s, Hong Kong, Singapore, South Korea and Taiwan became known as the Asian Dragons. In the 1990s, Thailand, Malaysia, Indonesia and the Philippines also experienced strong growth, earning them the name of Asian Tigers.
4. <http://www.e-ir.info/2014/10/16/the-asian-tigers-from-independence-to-industrialisation/>

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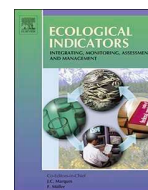


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# Environmental Kuznets curve revisited: An analysis using ecological and material footprint

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## ARTICLE INFO

### Keywords:

Ecological footprint  
Material footprint  
Economic growth  
Environmental Kuznets curve  
Energy consumption  
Urbanization rate  
Globalization  
Asian economies

## ABSTRACT

The study employed ecological and material footprint from the consumption perspective as a holistic measure of human pressure on the environment to examine the environment-economic growth nexus. Particularly, Environmental Kuznets curve hypothesis has been tested for the group of thirty-seven Asian countries. These are further analyzed into five Asian sub-regions, namely; West-, Central-, South-, East-and Southeast Asian countries over the period of 1991 to 2017. Panel cointegration, Pooled mean group, dynamic ordinary least square and differenced panel generalized methods of moments have been applied. The analysis reveals a mixture of results for the presence of EKC when using ecological footprint. EKC exists for Central-and East Asian countries, but not in case of West-, South-and Southeast Asian countries. Whereas results support EKC when we used material footprint indicator except central Asia. Energy consumption increases the ecological and material footprint. In addition, overall globalization and urbanization enhances ecological and material footprint. From the outcome of this empirical work, a number of policy recommendations have been discussed.

## 1. Introduction

The world today is confronted with the surge in global environmental pollution and maintaining economic development. With the massive increase in the green-house gases (GHG) emission, the environment has come to the forefront of the contemporary issues both for developed and developing nations. This has resulted due to the extensive use of natural resources and fossil-fuel to enlarge the production level. Over the decades, the world has experienced significant growth in economic and social development and consequentially moved toward resource and energy-intensive lifestyle. While around 70 percent of energy demand fulfil by non-renewable energy (World development Indicator, 2018). Therefore the focus has been given on the role of energy conservation, pollution control and renewable energy to reduce the environmental impact of such a lifestyle. Both unilateral and multilateral attempt have been made by different nations to devise the policies to tackle the issue.

In recent years, an enormous volume of research was conducted to devise the plan for better environmental management. Further, it has attracted the attention of the researcher to investigate the relationship between economic growth, energy consumption and environmental degradation (Salahuddin and Gow, 2014; Salahuddin et al., 2016). Various scenario-based forecasting and empirical analysis have been

attempted in different regions and countries. A significant portion of studies aims to test the existence of the Environmental Kuznets curve (EKC) hypothesis. EKC claims the inverted U-shaped association between growth-emissions nexus (Grossman and Krueger, 1991). Enormous empirical studies verify the existence of an inverted U-shaped relationship (Liu et al., 2007; Bilgili et al., 2016; Shahbaz et al., 2017; Fakher, 2019). Many have argued that service sector, the emergence of information-intensive industries, technological innovation, and higher expenditures on the environment played an important role in framing the EKC (Cole, 2004; Grossman and Krueger, 1996). Stern (2004) describes, the relationship between economic growth and environmental degradation with international trade. However, different sets of policy recommendation have been initiated based on their results for different countries to overcome these environmental issues.

Extensive studies have been conducted to examine the driving factors behind environmental pollution. Given the fact that CO<sub>2</sub> emission is the primary cause of climate change, majority of studies used it as an indicator of environmental pollution. However it is criticized to use it as sole proxy of environmental pollution. Since it ignore other major pollutant which too contributes to environmental deterioration (Al-Mulali et al., 2015; Wackernagel and Rees, 1998). Over the year, material consumption has also increasing and become important indicator for resource efficiency. Though some country reduced domestic

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material extraction but its consumption increased as through international trade. Hence Wiedmann et al. (2015) developed material footprint (MF); a consumption based indicator of resource use. They uses the world input–output data with trade and derived MF indicator as trade adjusted measure or called as consumption-based indicator. It precisely measure the origin of pressure to natural resources and demand of material from higher-income countries. They show it as alternate measure to examine the sustainability across countries. On the other hand, degradation in mining, forestry land, oil, grazing land and so forth is extremely important. So outcome may be misleading when using CO<sub>2</sub> emissions solely as proxy for environmental pollution. Therefore, one must use inclusive environmental indicator to obtain better understanding between economic growth and environmental damage to the country. For this purpose the study employed EF and MF to compute cumulative human pressure on the environment.

The concept of Ecological footprint (EF) was initially developed by Rees (1992) and later introduced by Wackernagel and Rees (1998). It measures six components (forest land, built-up land, grazing, cropping, fishing grounds and carbon footprint which includes carbon dioxide (CO<sub>2</sub>) emissions within the carbon footprint<sup>1</sup>. It can be described as pressure of human activity on the nature (Bartelmus, 2008; Kitzes and Wackernagel, 2009). It can be used for policy setting and easy to monitor. It is measured in terms of global hectare of land (bio productive) required for carrying out human activities in a sustainable manner.

Asia's EF continues to rise at a faster pace than Earth's bio capacity in these regions and relatively higher than all other regions. Furthermore, EF and MF shows considerable variabilities across Asian region. This is mainly due to sharp increase in population, higher growth of consumption expenditure, and decline in the productive ecological resources along with inadequate resource management, habitat destruction and environmental pollution. Figs. 1–5 show the ecological footprint of considered five Asian sub regions by land use type. Overall rise in Asia's EF is contributed by China (Galli et al., 2012), whereas ecological footprint in the West and Central Asia is also showing increasing trend with highest per capita growth than any other region. United Arab Emirates hold the largest average ecological footprint at 10.7 gha per person, while Yemen has lowest 1.0 gha per person. In case of Central Asia, Kazakhstan embraces with the highest ecological footprint followed by Turkmenistan, Uzbekistan and Azerbaijan and lowest was accounted in Tajikistan. In driving the overall ecological footprint on a regional level, dynamics and population play different roles. West-and Central Asia experienced rapid increase in per capita ecological footprint, between 1961 and 2016, it grew by 126% and 146% while population increased by 155% and 465% respectively (Lin et al., 2018). This led to the overall ecological footprint to be increased by six fold in West and Central Asian regions.

Per capita ecological footprint in South Asia shows little variation and concentrated around 1 gha per person except Bhutan. It has highest ecological footprint of 4.49 gha per person, followed by Sri Lanka and India for the year 2016. Demographic transition, energy- intensive production, and industrialization cause huge green-house gas emission and greater requirement of built-up land which increase ecological footprint of South Asian countries (Galli et al., 2012; Niccolucci et al., 2012). Though Bangladesh happens to be the smallest territory in South Asia, its usage of built-up land is rapidly increasing.

In the early 2000s, China's total ecological footprint has surpassed that of the US and experience drastically increase over the last 15 years. China happens to be the world's largest population, in recent years their population has stabilized and showed declining trend. China has the largest share in world EF, but in terms of per capita, it has less than the world average (EF-GPN, 2018). Moreover, the scenario of EF per person in East Asian region (Fig. 4) is highest in Mongolia (9.49 gha) followed

by Korea (5.81 gha) and Japan (4.74 gha). Carbon footprints were one of the major contributors in ecological footprint in Japan. In the late 1990s carbon footprint increased 13 times such that 65 percent of total EF consumption was caused by carbon footprint (Japan's Ecological Footprint, 2019). Lastly, Fig. 5 shows the ecological footprint consumption by Southeast Asian countries. It can be observed from the figure that Singapore holds the largest EF followed by Brunei, Malaysia, Thailand and other Southeast Asian countries. In the recent report from World Wildlife Fund (2018) it was observed that use of natural resources and the population has led to the environmental damages in Singapore. Furthermore, Vietnam, Myanmar, Indonesia and Cambodia have almost same level of ecological footprint consumption during 2016. Similar trends persist in case of material footprint as it increases over the period of time.

## 2. Literature review

The pioneering work of Grossman and Krueger (1991) advocated that the relationship between economic growth and environmental pollution follows an inverted U-shape relationship. It states that in the early stage of country's growth, environmental pollution deepens, after reaching at certain threshold level, environmental pollution starts declining. It is a preference mechanism and priority setting between economic growth and environmental pollution for developing countries. Advocate of EKC hypothesis argued for focus on economic growth first then preferences will shift to clean environment. In short, there exists a non-linear association between growth-emissions.

Based on the EKC argument, extensive research has been done to empirically test the income-emissions. Simple classification and review of all literature is out of scope of this study. Various studies has been conducted and differ in terms of method, sample countries, study period, variables and results. For detail survey of literature one can see Table 1. For the simplicity, literature has been reviewed into strand. The first strand includes studies based on CO<sub>2</sub> emissions as an indicator of environmental pollution. Since international negotiation targeted the CO<sub>2</sub> emissions to fight the climate change. Extensive studies used CO<sub>2</sub> emissions (total or per capita) and test the EKC hypothesis using different econometric methods (Ozturk and Acaravci, 2010; Apergis and Ozturk, 2015; Charfeddine and Mrabet, 2017; Ulucak and Bilgili, 2018; Fakher, 2019). Along with economic growth as a key variable in empirical testing of EKC, consumption of energy, financial development, urbanization, trade openness are identified as the determinants of environmental degradation (Kasman and Duman, 2015; Ansari et al., 2019b; Pablo-Romero and Sanchez-Braza, 2017; Destek et al., 2018).

Sarkodie and Ozturk (2020) investigate the relationship between energy efficiency and energy consumption in Kenya by using ARDL approach. The empirical finding exposed that the use of energy increases CO<sub>2</sub> emissions. Moreover, inverted U-shaped EKC is found between economic growth and carbon emissions. Shahbaz et al. (2016) explored the role of globalization on selected African countries. The empirical findings proves the development of globalization reduces CO<sub>2</sub> emissions. Their study also supported the presence of EKC in six countries. Ahmed et al. (2019) studied the impact of trade openness on environmental degradation for selected eight developing countries. They revealed that energy consumption, export and country's growth remained significant factor for emissions and found the inverted U-shaped association between economic growth and environmental pollution. Arrow et al. (1995) found people tend to spend more proportionately as economic growth happens. Recently several studies highlighted role of trade and globalization in increasing the demand of goods and services. Shahbaz et al. (2015) finds that impact of trade openness on CO<sub>2</sub> emissions depends on its economic and financial development. Antweiler et al. (2001) reveals that trade openness expected to improve CO<sub>2</sub> emissions. In recent study by Salahuddin et al. (2016) stated that increase in financial growth across different regions in GCC may cause higher carbon dioxide (CO<sub>2</sub>) emissions. Pao and Tsai (2011)

<sup>1</sup> For more details see lin et al. (2018)

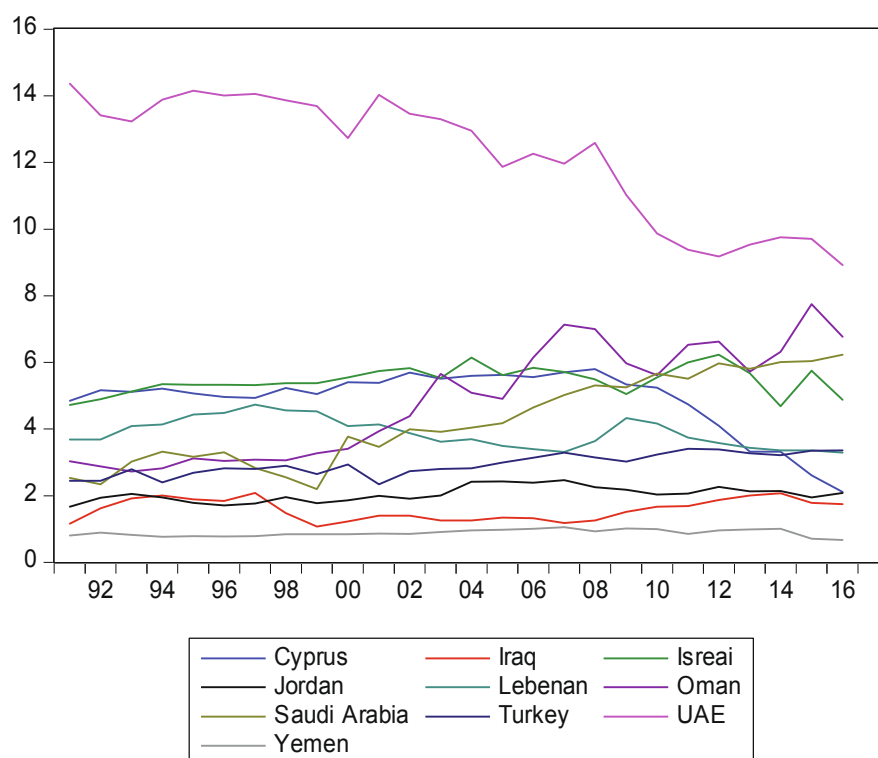


Fig. 1. Ecological footprint per capita consumption by West Asia.

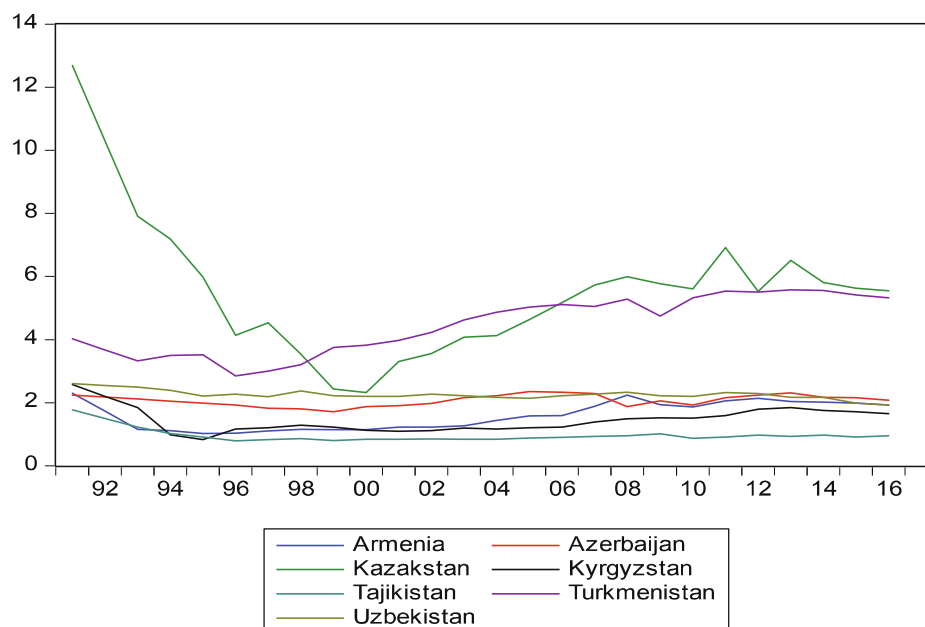


Fig. 2. Ecological footprint per capita consumption by Central Asia.

showed that massive use of energy enhance  $\text{CO}_2$  emissions. [Shahbaz et al. \(2016\)](#) reported that globalization and consumption of energy increases emissions in China. [Kalayci and Hayaloglu \(2018\)](#) reach the same conclusion for NAFTA countries. Moreover, [Xu et al. \(2018\)](#) applies ARDL approach and causality test to study the dynamic association between financial development, globalization and  $\text{CO}_2$  emissions using time series data for the period 1971–2016 in Saudi Arabia. They find globalization to be insignificant on environment quality. Similar results were also pointed out by [Haseeb et al. \(2018\)](#) for BRICS

countries. A recent study by [Zhang \(2019\)](#) found that there is no evidence of the environmental Kuznets curve in Central Asia when he used the Pedroni cointegration and the Dumitrescu-Huulin granger causality test. His results further reveals that urbanization plays an important role in explaining carbon emissions.

The second group of studies used ecological footprint as an indicator of environmental quality, and tested the EKC hypothesis using real GDP, square of real GDP. This group further extended to include trade openness, financial development, energy consumption, globalization

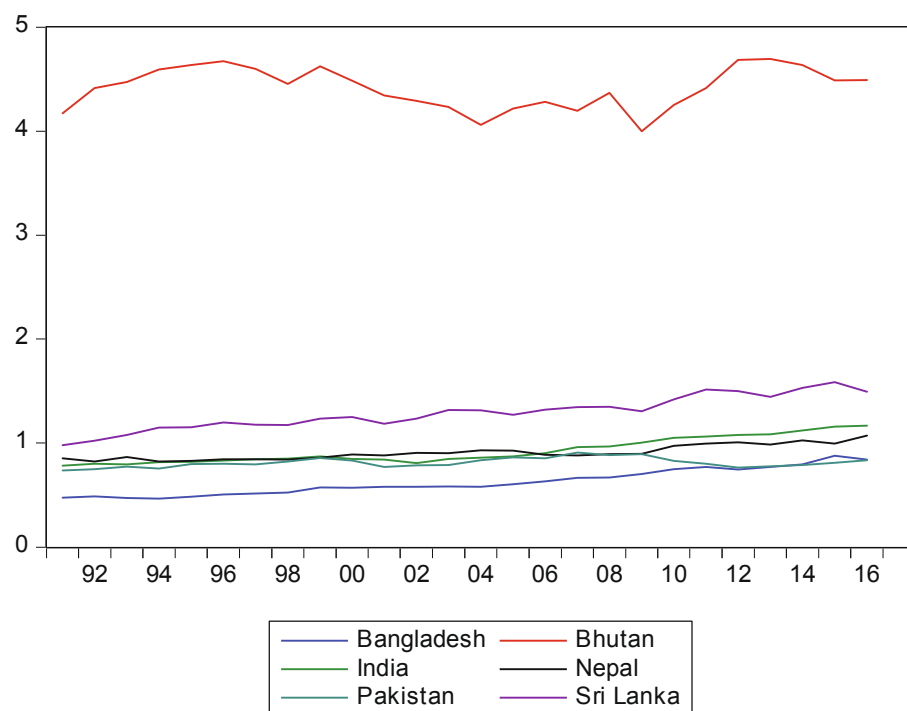


Fig. 3. Ecological footprint per capita consumption by South Asia.

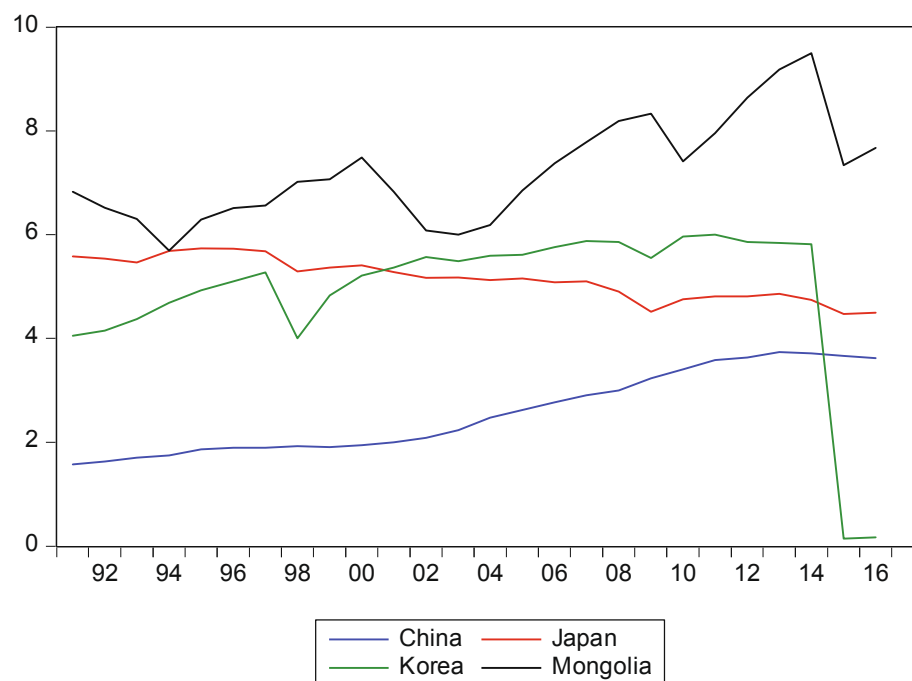


Fig. 4. Ecological footprint per capita consumption by East Asia.

and urbanization as additional independent variables. Main findings of previous studies are summarized in Table 1. In considering the validity of EKC, Charfeddine and Mrabet (2017), Aşıcı and Acar (2016), Mrabet and Alsamara (2017), and Fakher (2019) confirmed the presence of EKC. In contrast Bagliani et al. (2008), Pablo-Romero and Sanchez-Braza (2017) did not support the EKC when using EF<sup>2</sup>. Galli et al.

(2012) found that “global ecological footprint increased in high income nations while in low and middle income countries it declined or remained constant”. Furthermore, Al-Mulali et al. (2015) analyzed the impact of real GDP, financial development and renewable energy consumption on ecological footprint (EF) for Caribbean and Latin American countries and did not find any evidence in support of EKC in low income nations while they revealed inverted U-shaped relationship in upper middle and high income countries. The findings of Moran et al.

<sup>2</sup> For more details see Table 1

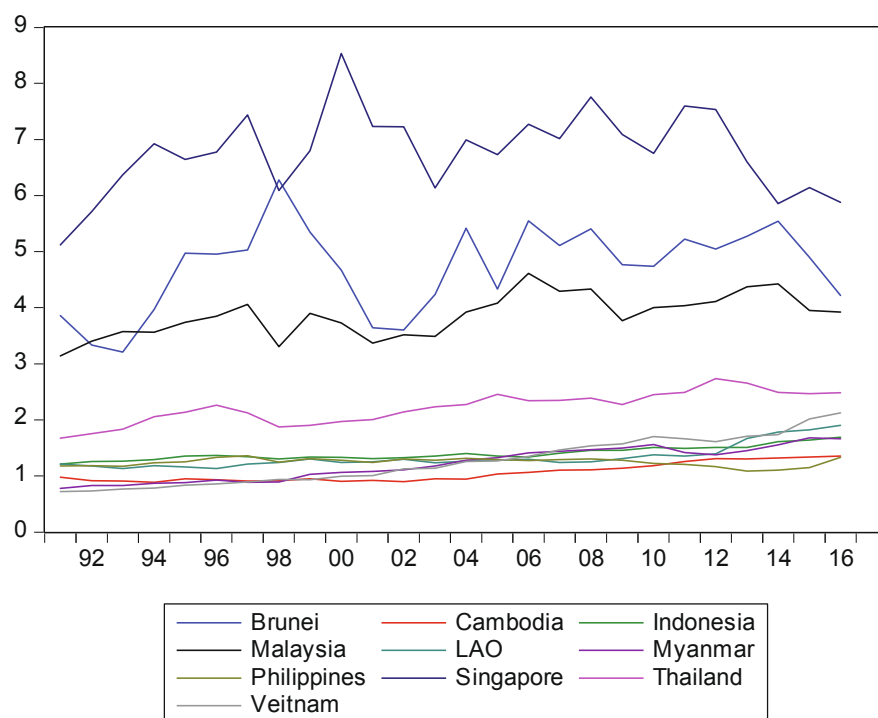


Fig. 5. Ecological footprint per capita consumption by Southeast Asia.

**Table 1**  
Summary literature review of EKC using Ecological footprint.

| Studies                               | Periods   | Countries                         | Estimation Methods                                         | Support EKC or not                                                   |
|---------------------------------------|-----------|-----------------------------------|------------------------------------------------------------|----------------------------------------------------------------------|
| Bagliani et al. (2008)                | 2001      | 144 countries                     | cross section OLS, Weighted LS                             | Not                                                                  |
| Caviglia-Harris et al. (2009)         | 1961–2000 | 146 countries                     | Panel fixed effect, 2SLS, GMM                              | Not                                                                  |
| Wang et al. (2013)                    | 2005      | 150 countries                     | special econometric approach                               | Not                                                                  |
| Al-Mulali et al. (2015)               | 1980–2008 | 93 countries                      | Panel fixed effect, GMM                                    | No for lower and middle income, yes for upper middle and high income |
| Hervieux and Darne (2016)             | 1961–2007 | 7 latin American countries        | Time series cointegration                                  | Not                                                                  |
| Aşıcı and Acar (2016)                 | 2004–2008 | 116 countries                     | Panel fixed effect                                         | Support                                                              |
| Mrabet and Alsamara (2017)            | 1980–2011 | Qatar                             | ARDL                                                       | Support                                                              |
| Charfeddine and Mrabet (2017)         | 1995–2007 | 15 MENA countries                 | Panel fully modified OLS and dynamic OLS                   | Support                                                              |
| Charfeddine (2017)                    | 1970–2015 | Qatar                             | Markow Switching Equilibrium model                         | Support                                                              |
| Pablo-Romero and Sanchez-Braza (2017) | 1995–2009 | 40 countries and EU-27            | Panel multilevel mixed effects                             | Not                                                                  |
| Ulucak and Bilgili (2018)             | 1961–2013 | 45 countries                      | CUP-FM, CUP-BC model                                       | Support                                                              |
| Destek et al. (2018)                  | 1980–2013 | European countries                | Fully modified OLS, dynamic OLS, mean group                | Not                                                                  |
| Hassan et al. (2019)                  | 1970–2014 | Pakistan                          | ARDL                                                       | Support                                                              |
| Fakher (2019)                         | 1996–2016 | Selected OECD countries           | Bayesian model averaging and weighted average least square | Support                                                              |
| Destek and Sarkodie (2019)            | 1977–2013 | 11 newly industrialized countries | Augmented mean group                                       | Support                                                              |

Note; FMOLS: fully modified ordinary least squares, ARDL: autoregressive distributed lag model, DOLS: dynamic ordinary least squares, MG: mean group, AMG: augmented mean group, FE: fixed effect, CUP-FM, CUP-BC: continuously updated fully modified, continuously updated bias corrected, GMM: generalized methods of moments.

(2008) revealed a positive relationship between economic growth and ecological footprint. Al-Mulali et al. (2015) claimed that in the panel of 93 countries, openness in trade increases EF while financial development reduces it. Sabir and Gorus (2019) used pooled cross country data for South Asian countries over the period 1975–2017 to investigate the effect of globalization and technological changes on the emissions. Their empirical findings show existence of EKC and positive effect of globalization on EF. Charfeddine and Mrabet (2017) examined the impact of economic growth and urbanization on ecological footprint and finds urbanization to be statistically significant and negative effect in the panel of 15 MENA countries. Teixidó-Figueras et al. (2016)

examines the international distributional analysis of natural resource indicator and found that urbanization increases the material footprint.

It is surprising that although substantial proportion of Asian countries is accountable for worlds environmental emissions, none of the accessible researcher have investigated environment Kuznets relationship by utilizing EF and MF indicator in the case of Asian countries. Thus, we contribute to the existing literature by employing these indicator. Secondly, the study examines the environmental effect of economic growth on EF and MF indicator (environmental degradation indicator) in determining the shape of EKC and devise appropriate policy implication. Third, to sustain empirical results and reach out



reliable policy conclusion, it is quite imperative to apply a robust method to overcome with this issue of heterogenous panel analysis. For this purpose, the Lagrange multiplier (LM) proposed by Breusch and Pagan (1980) is employed to identify the presence of cross sectional dependence. Fourth, second generation long run estimates Pesaran et al. (1999) Pooled mean group (PMG), Stock and Watson (1993) dynamic ordinary least square (DOLS) and Arellano and Bond (1991) differenced panel generalized methods of moments (GMM) is applied to examine the long run coefficients and to ensure the accuracy and robustness. Finally, Asian countries are potential contributor to environment degradation globally and at the same time, demand for energy in these countries is high. As literature is scant on examine the Asian sub region countries this study will adds to the debate on the EKC. Therefore, it is essential to analyze the validity of the EKC hypothesis in these sub regions to fill the research gap and to make predictable policy implication. Furthermore, control variables such as energy consumption, urbanization and globalization is used as additional variables as to observe their effects on environment. The rest of the paper is organized as follows: Section 3 discusses “Data and Empirical modeling”. Section 4 reports “Econometric results”. “Conclusion and discussion of results” is presented in section 5

### 3. Data and empirical modeling

We employed annual data spanning from 1991 to 2017 for the 37 Asian countries. Period of analysis is taken based on the availability of data. To examined the validity of Environmental Kuznets curve (EKC) hypothesis and measure the comparative performance of  $G$ ,  $UR$  and  $EC$  on environmental degradation we have classified the Asian countries into five sub-regions; (i) West Asia (Israel, Jordan, Oman, Turkey, Lebanon, United Arab Emirates (UAE), Saudi Arabia, Iraq, Cyprus and Yemen), (ii) Central Asia (Kazakhstan, Armenia, Azerbaijan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan), (iii) South Asia (India, Bangladesh, Nepal, Sri Lanka, Pakistan and Bhutan), (iv) East Asia (China, Japan, Korea and Mongolia), (v) Southeast Asia (Indonesia, Malaysia, Singapore, Myanmar, Brunei, Philippines, Thailand, Vietnam, Cambodia and Lao). Then, using per capita ecological footprint and material footprint as an indicator for environmental pollution and we establish a Kuznets curve model.

Concerning the driving factors of the above mentioned environmental indicators, we have taken major socio-economic and geophysical drivers for both EF and MF indicator. This will allow us to do a comparative analysis as both share common driving factors.

In order to obtain a better understanding of driving factors, we follows the similar literature that analyze the drivers of such indicators and following variables have been then used in this paper.

**Economic Growth:** Since main motives is to examine EKC, we have added economic growth and square of economic growth as main variable. It can be seen as affluence variable that represent income level and economic activities in the economy. It represent the production level of an economy and an increase in the output will demand more resources and increase EF and MF. While overtime with increase in income, people will demand clean environment and efficient use the ecological resources which reduced ecological and material footprint.

**Urbanization:** During the economic development, rural–urban migration happens for occupations and succeeding urban growth. The stretch of urban and periphery will grow along with construction work, expansion of supply, transport and other infrastructures for connecting with urban centers. Hence expansion of economic activities resulted in higher resource demand (Liddle and Lung, 2010). However, Urbanization may provide economies of scale and promote resources efficiency and enable to minimize environmental impact (Weisz and Steinberger, 2010). The ecological modernization theory advocated that the modernity of civil society leads to emergence of ecologically rational institutions, policies, and technologies that reduces the environmental degradation. Urbanization may reduce the EF and MF in

urban areas through better management and efficient use of space, transportation and resources. It is taken as the percentage of a country's population living in urban areas.

**Energy Consumption:** It is considered as one of the key factor for escalating environmental damage. Major part of energy demand is fulfilled by fossil-fuel which responsible for major growth in emission. It is used in the literature as important determinant of environmental degradation. Particularly emission of major pollutants such as  $CO_2$  and  $SO_2$  are highly correlated with energy consumption. Several studies consider it as an additional variable in the basic EKC hypothesis. It connect environmental quality with economic growth. Recent empirical studies have established the link between energy consumption and environmental degradation.

**Globalization:** Globalization connect economic growth through enhancing international trade and investment. Hence it has been seen as key element to development of a country. Globalization promoted through social, political and economic means. However its impact on environmental quality is less known, it may have favorable and unfavorable effects. It reduce cross-border restrictions on trade, investment and labor movement. It can enhance technological capacity through foreign direct investment, competition and technologies transfer. Therefore it provides resource efficiency and better management of environmental resources. It is known as the technique effect of globalization. On the contrary globalization may deepen environmental degradation through enhancing income and economic activities. This is called as the scale effect channel. Finally, the composition effect of globalization starts when an economy start to shift from farming to manufacturing and, finally, to the services sector. In this manner, production methods might be modified as the economy evolves from the manufacturing to the services sector. Depends upon the magnitude of different effect, the impact of globalization on EF and MF will depict. The log linear quadratic multivariate function is presented as follows:

$$\ln EF_{it} = \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{it}^2 + \beta_3 \ln EC_{it} + \beta_4 \ln URB_{it} + \beta_5 \ln G_{it} + \mu_{it} \quad (1)$$

$$\ln MF_{it} = \alpha_0 + \alpha_1 \ln Y_{it} + \alpha_2 \ln Y_{it}^2 + \alpha_3 \ln EC_{it} + \alpha_4 \ln URB_{it} + \alpha_5 \ln G_{it} + \epsilon_{it} \quad (2)$$

Where  $i$  represent the cross-sectional and  $t$  is the time dimension in panel estimation (1991–2017). The  $\beta_1, \dots, \beta_5$  and  $\alpha_1, \dots, \alpha_5$  indicate the long run elasticity with respect to EF and MF. The variables<sup>3</sup> name, their description, date source and the unit of measurement is reported in Table 2.

#### 3.1. Empirical methodology

Because this empirical paper attempts to analyze the environmental Kuznets curve hypothesis, this paper included the square of economic growth. To this end, if the slope coefficient for the economic growth (square of economic growth) is positively ( $\beta_{2i} > 0$ ) and negatively ( $\beta_{2i} < 0$ ) significant, “an inverted U-shaped” association between economic growth and the EF/MF will result, which represents environmental Kuznets curve (EKC) hypothesis. Thirty seven Asian countries will be analyzed categories by Asian sub panels as West Asia-, Central Asia-, South Asia-, East Asia- and Southeast Asian countries.

Since the period of study is long enough, we have applied time series technique of unit-root (stationarity), cointegration, and long- and short-run results estimation. To assess the stationarity of the variables, a number of unit root tests are performed. After checking the presence of unit-root that variables are of first-difference stationary, the Pedroni (1999, 2004) and Kao (1999) panel cointegration test is then used to check the long-run association among the variables. Once it is

<sup>3</sup> the variables are converted into natural log form to interpret the estimated coefficients (Paramati et al., 2017)

**Table 2**  
Variable description.

| Variables              | Symbol | Description                                                                                                                  | Units                           | Source                            |
|------------------------|--------|------------------------------------------------------------------------------------------------------------------------------|---------------------------------|-----------------------------------|
| Ecological Footprint   | lnEF   | Sum of crop land, grazing land, forest land, fishing, infrastructure and carbon                                              | Million metric tons (MMT)       | EF-GPN, 2018                      |
| Material footprint     | lnMF   | Sum of biomass, fossil fuels, metal ores and non metallic minerals                                                           | Tonnes per capita               | Wiedmann et al. (2015) (MFN-PNAS) |
| Gross domestic product | lnY    | Gross domestic product per capita                                                                                            | Constant US dollar 2010         | WDI, 2018                         |
| Energy consumption     | lnEC   | Energy use per capita                                                                                                        | kg of oil equivalent per capita | WDI, 2018                         |
| Globalization index    | lnG    | measured by (Dreher, 2006) as KOF index of globalization consist of mainly three parameters (economic, political and social) | KOF index                       | KOF Database                      |
| Urbanization rate      | lnUR   | Urbanization rate (urban population/total population)                                                                        | as % of total                   | WDI, 2018                         |

GPN global footprint network, WDI world development indicator, SEI swiss economics institution, MFN-PNAS the material footprint of nations – proceedings of the national academy of sciences of the USA.

confirmed that the variables are cointegrated, the pooled mean group estimation (PMG) developed by Pesaran and Smith (1995); Pesaran et al. (1999) is used to estimate the long run association among the analyzed variables. In addition, to check for the accuracy and robustness of the obtained results from the panel PMG estimates, the panel dynamic ordinary least square (DOLS) technique developed by Stock and Watson (1993) is employed. The former is basically an augmentation of Autoregressive Distributed lag model, and take care of heterogeneity which restrict long run coefficients.<sup>4</sup> It allow short run coefficients to vary across countries together with error variances and intercepts. There is also an adjustment mechanism toward long-run equilibrium from any short run deviation known as error correction term (ECT). Hence, the possible endogeneity can also be removed by applying suitable form of lags of different variables in the ECT. The specification of error correction model of PMG is given by;

$$\Delta m_{it} = \alpha_i (m_{i,t-1} - \varphi_i' n_{i,t-1}) + \sum_{j=0}^{y-1} \rho_{ij}^* \Delta m_{i,t-1} + \sum_{j=0}^{x-1} \delta_{ij}^* \Delta n_{i,t-j} + \varphi_i + \mu_{it} \quad (3)$$

Here,  $m$  portrays the ecological footprint or material footprint (dependent variable),  $(m_{i,t-1} - \varphi_i' n_{i,t-1})$  represents the long run deviation,  $\alpha_i$  is speed of adjustment associated with error correcting terms. There is an evidence of no cointegration if  $\alpha_i = 0$  which assumed to be negative and statistically significant. Vector  $\delta$  and vector  $\varphi_i$  constitute the short run and long run coefficients<sup>5</sup> respectively.  $\mu_{it}$  is the residual term and finally  $\varphi_i$  is country specific effect unobserved time invariant.

DOLS is quite productive in eliminating the autocorrelation issue in the residual terms and endogeneity problem in the regressors (Bhattacharya et al., 2016). Moreover, by employing parametric approach, DOLS method eliminates the problem of explanatory variables and its lags. Apart from PMG and DOLS, we have also applied panel GMM which allows us to exploit the dynamics of data through using appropriate lag length as inbuilt instrument and also incorporates the given panel framework. Arellano and Bond (1991) difference GMM estimator is used to gauge dynamic panel data analysis. The difference GMM tackle the endogeneity of regressor or endogenous variables and also removes the any connection between time-invariant country effect and explanatory variables. It deals with the issue of autocorrelation and cross-sectional dependence as it applied instrumental variable estimation technique.

Before applying panel data technique, first, we have checked the presence of cross-sectional dependence (CSD) in the Asian sub-region countries. To test CSD, Lagrange multiplier (LM) technique developed by Breusch and Pagan (1980) has been applied<sup>6</sup>. According to the results given in Table 3, the null of cross-sectional independence is rejected in all the countries of all the Asian groups at 1 percent significance level. Hence it confirms the presence of CSD, so we have applied the second generation panel data method to account for CSD.

## 4. Econometric results

### 4.1. Unit root analysis

Testing the stationarity of the data is an important step in an empirical analysis. If its mean and autocovariances do not depend on time

<sup>4</sup> In literature, presently there are 3 dynamic approaches, the first is DFE (dynamic fixed effects) in which only error variances and intercept are allowed to vary and it completely avoids the heterogeneity across cross sections. The second is MG (Mean Group) given by Pesaran and Smith (1995) which allows short-long run coefficients, error variances and intercepts to vary. And, finally Pesaran and Smith (1995) PMG (Pooled mean group) approach where short run, error variances and intercepts are allowed to vary across groups.

<sup>5</sup> dependent variable w.r.t. each regressors shown by  $n_{i,t-1}$ .

<sup>6</sup> in case of panels with  $T > N$ , this test performs better



**Table 3**  
Test for cross sectional dependence.

| Whole Panel  |          |       | South Asia     |         |       |
|--------------|----------|-------|----------------|---------|-------|
| Variables    | BP-LM    | Prob  | Variables      | BP-LM   | Prob  |
| lnEF         | 4853.23  | 0.00* | lnEF           | 96.42   | 0.00* |
| lnMF         | 8878.35  | 0.00* | lnMF           | 312.45  | 0.00* |
| lnY          | 11607.14 | 0.00* | lnY            | 393.98  | 0.00* |
| lnY2         | 11657.66 | 0.00* | lnY2           | 393.59  | 0.00* |
| lnEC         | 5925.10  | 0.00* | lnEC           | 199.10  | 0.00* |
| lnGI         | 14411.21 | 0.00* | lnGI           | 342.65  | 0.00* |
| lnUR         | 12625.36 | 0.00* | lnUR           | 361.60  | 0.00* |
| West Asia    |          |       | East Asia      |         |       |
| Variables    | BP-LM    | Prob  | Variables      | BP-LM   | Prob  |
| lnEF         | 294.85   | 0.00* | lnEF           | 63.69   | 0.00* |
| lnMF         | 434.40   | 0.00* | lnMF           | 41.71   | 0.00* |
| lnY          | 443.98   | 0.00* | lnY            | 146.79  | 0.00* |
| lnY2         | 443.69   | 0.00* | lnY2           | 146.85  | 0.00* |
| lnEC         | 275.54   | 0.00* | lnEC           | 76.53   | 0.00* |
| lnGI         | 815.51   | 0.00* | lnGI           | 155.19  | 0.00* |
| lnUR         | 877.42   | 0.00* | lnUR           | 136.12  | 0.00* |
| Central Asia |          |       | Southeast Asia |         |       |
| Variables    | BP-LM    | Prob  | Variables      | BP-LM   | Prob  |
| lnEF         | 145.00   | 0.00* | lnEF           | 387.04  | 0.00* |
| lnMF         | 275.26   | 0.00* | lnMF           | 813.75  | 0.00* |
| lnY          | 446.08   | 0.00* | lnY            | 1016.78 | 0.00* |
| lnY2         | 445.26   | 0.00* | lnY2           | 1026.20 | 0.00* |
| lnEC         | 174.89   | 0.00* | lnEC           | 453.49  | 0.00* |
| lnGI         | 526.20   | 0.00* | lnGI           | 1011.58 | 0.00* |
| lnUR         | 307.02   | 0.00* | lnUR           | 792.11  | 0.00* |

\*denote rejection of null of cross sectional independence at 1 per cent significance level.

dimension, a variable is said to be stationary. Because this empirical study uses a panel data technique and presence of CSD, the stationary properties of all the variables have been tested by three different panel unit root test; namely, IPS test developed by Im et al. (2003), non-parametric Fisher type ADF test and Phillips-Peron (PP) test developed by Maddala and Wu (1999). In the context of panel unit root analysis these tests have also been used in the previous studies (Charfeddine and Mrabet, 2017; Ansari et al., 2019a; Ansari et al., 2019b). These tests assumes individual unit root and allows for panel heterogeneity for all the panel units in the process of autoregressive coefficients which may differ across countries. The IPS, ADF and PP merge individual series to derive panel unit root test results and work under the null of non-stationary (unit root) as again an alternate of stationary (no unit root).

The results from the panel unit root tests are reported in panel I, II and III, of Table 4, namely, the IPS, ADF and PP unit root tests. It can be observed from the Table 4 that all the variables<sup>7</sup> contain unit root but after first-difference they become stationary. Hence the next step in the analysis is to examine the long-run association among the variables.

#### 4.2. Cointegration analysis

The results from two different panel cointegration test are reported in panel a & b of Table 5. First is residual-based heterogeneous Pedroni (1999, 2004) test with various individual effects for CSD is estimated to serve the objective. It has seven different test statistics to examine the null of no cointegration with first three are non-parametric approach (panel  $\nu$  statistics, panel  $\rho$  statistics, and panel  $PP$  statistics) while panel ADF statistics is a parametric approach, these tests are known as within dimension statistics. The other individual AR coefficients are group  $\rho$  statistics, group  $PP$  statistics (nonparametric) and group ADF statistics (parametric) are known as between dimension approach as group mean statistics. The study also applied Kao (1999) cointegration test given by Maddala and Wu (1999) for robustness purpose.

Tables 5 & 6 reveals the panel cointegration results for the West-

**Table 4**  
Panel unit root test result.

| Panel I: Im, Pesaran and Shin (IPS) |           |                   |                   |                   |                   |
|-------------------------------------|-----------|-------------------|-------------------|-------------------|-------------------|
| Variables                           | Level     | First difference  |                   |                   |                   |
|                                     |           | intercept         | Intercept & trend | intercept         | Intercept & trend |
| Whole panel                         | lnEF      | 1.45              | (2.42*            | -21.88*           | -18.98*           |
|                                     | lnMF      | 1.07              | -7.27*            | -28.13*           | -24.40*           |
|                                     | lnY       | 8.97              | -0.78             | -14.36*           | -12.11*           |
|                                     | lnY2      | 10.59             | -2.03**           | -14.03*           | -12.03*           |
|                                     | lnEC      | 0.45              | -3.11*            | -21.53*           | -20.60*           |
|                                     | lnGI      | -4.60*            | -0.01             | -21.31*           | -21.35*           |
|                                     | lnUR      | 0.56              | -1.83**           | -7.69*            | -11.82*           |
|                                     | lnUR      | 0.56              | -1.83**           | -7.69*            | -11.82*           |
| West Asian countries                | lnEF      | 2.19              | 1.21              | -12.53*           | -11.48*           |
|                                     | lnMF      | -1.52***          | -3.25*            | -10.70*           | -8.88*            |
|                                     | lnY       | 0.6               | 3.08              | -6.00*            | -4.62*            |
|                                     | lnY2      | 0.7               | 3.07              | -5.97*            | -4.62*            |
|                                     | lnEC      | 0.48              | 1.49              | -13.89*           | -14.21*           |
|                                     | lnGI      | -1.07             | 1.86              | -10.50*           | -11.99*           |
|                                     | lnUR      | -1.64***          | -0.79             | -19.08*           | -21.82*           |
|                                     | lnUR      | -1.64***          | -0.79             | -19.08*           | -21.82*           |
| Central Asian countries             | lnEF      | -2.87*            | -3.96*            | -7.60*            | -5.94*            |
|                                     | lnMF      | -1.13             | -5.43*            | -20.38*           | -20.29*           |
|                                     | lnY       | 2.56              | -4.71*            | -7.34*            | -4.42*            |
|                                     | lnY2      | 2.82              | -7.09*            | -7.20*            | -4.40*            |
|                                     | lnEC      | -4.13*            | -7.20*            | -8.60*            | -6.68*            |
|                                     | lnGI      | -3.79*            | -0.46             | -7.62*            | -7.42*            |
|                                     | lnUR      | -0.25             | -2.52*            | 0.43              | -3.51*            |
|                                     | lnUR      | -0.25             | -2.52*            | 0.43              | -3.51*            |
| South Asian countries               | lnEF      | 2.04              | 0.06              | -9.92*            | -8.77*            |
|                                     | lnMF      | 3.86              | -3.91*            | -11.52*           | -9.87*            |
|                                     | lnY       | 9.76              | 2.28              | -6.91*            | -7.45*            |
|                                     | lnY2      | 11.07             | 2.99              | -6.38*            | -7.45*            |
|                                     | lnEC      | 3.01              | 2.23              | -9.28*            | -9.42*            |
|                                     | lnGI      | 0.35              | -0.78             | -9.94*            | -9.44*            |
|                                     | lnUR      | 1.63              | -1.36***          | 0.52332           | -12.08*           |
|                                     | lnUR      | 1.63              | -1.36***          | 0.52332           | -12.08*           |
| East Asian countries                | lnEF      | 1.12              | -1.89             | -5.44*            | -4.39*            |
|                                     | lnMF      | -0.6              | -3.61*            | -6.80*            | -5.72*            |
|                                     | lnY       | 1.33              | -0.61             | -5.36*            | -3.77*            |
|                                     | lnY2      | 2.04              | -1.40***          | -5.33*            | -3.70*            |
|                                     | lnEC      | 1.84              | -1.43***          | -5.49*            | -5.40*            |
|                                     | lnGI      | -2.84*            | -0.31             | -7.17*            | -7.42*            |
|                                     | lnUR      | -0.62             | -0.48             | -3.46*            | -2.02**           |
|                                     | lnUR      | -0.62             | -0.48             | -3.46*            | -2.02**           |
| Southeast Asian countries           | lnEF      | 0.74              | -1.30***          | -12.12*           | -10.47*           |
|                                     | lnMF      | 1.95              | -0.82             | -13.22*           | -9.92*            |
|                                     | lnY       | 6.25              | -1.83**           | -6.75*            | -6.88*            |
|                                     | lnY2      | 7.61              | -2.25**           | -6.68*            | -6.81*            |
|                                     | lnEC      | 0.35              | -2.25*            | -9.72*            | -9.11*            |
|                                     | lnGI      | -3.03*            | -0.69             | -11.88*           | -10.86*           |
|                                     | lnUR      | 0.8               | 0.48              | -7.00*            | -5.55*            |
|                                     | lnUR      | 0.8               | 0.48              | -7.00*            | -5.55*            |
| Panel II: Fisher type ADF           |           |                   |                   |                   |                   |
| Variables                           | intercept | Intercept & trend | intercept         | Intercept & trend |                   |
| Whole panel                         | lnEF      | 94.33***          | 126.20*           | 529.06*           | 429.80*           |
|                                     | lnMF      | 91.92***          | 215.19*           | 609.16*           | 799.26*           |
|                                     | lnY       | 33.69             | 118.06*           | 363.41*           | 298.57*           |
|                                     | lnY2      | 29.9              | 153.48*           | 356.22            | 294.71*           |
|                                     | lnEC      | 119.29*           | 144.48*           | 514.03*           | 486.56*           |
|                                     | lnGI      | 155.78*           | 89.04             | 518.87*           | 474.28            |
|                                     | lnUR      | 328.91*           | 124.69*           | 89.27***          | 368.92*           |
|                                     | lnUR      | 328.91*           | 124.69*           | 89.27***          | 368.92*           |
| West Asian countries                | lnEF      | 13.52             | 23.85             | 158.00*           | 139.36*           |
|                                     | lnMF      | 35.06**           | 49.81*            | 132.60*           | 101.50*           |
|                                     | lnY       | 15.06             | 16.77             | 94.85*            | 71.25*            |
|                                     | lnY2      | 14.34             | 16.19             | 93.79*            | 70.35*            |
|                                     | lnEC      | 23.47             | 14.05             | 168.30*           | 186.81*           |
|                                     | lnGI      | 25.45             | 22.5              | 139.44*           | 137.78*           |
|                                     | lnUR      | 276.12*           | 34.33**           | 47.60*            | 291.51*           |
|                                     | lnUR      | 276.12*           | 34.33**           | 47.60*            | 291.51*           |
| Central Asian countries             | lnEF      | 37.02*            | 45.05*            | 78.87*            | 57.80*            |
|                                     | lnMF      | 29.68*            | 58.62*            | 147.34*           | 446.17*           |
|                                     | lnY       | 10.68             | 51.40*            | 74.94*            | 49.84*            |
|                                     | lnY2      | 9.83              | 78.08*            | 74.31*            | 47.84*            |
|                                     | lnEC      | 51.92*            | 73.28*            | 88.49*            | 68.16*            |
|                                     | lnGI      | 39.52*            | 15.02             | 78.41*            | 72.89*            |
|                                     | lnUR      | 18.12             | 34.95*            | 19.35             | 39.96*            |
|                                     | lnUR      | 18.12             | 34.95*            | 19.35             | 39.96*            |

(continued on next page)

<sup>7</sup> Some are stationary at level.

Table 4 (continued)

| Panel:I Im, Pesaran and Shin (IPS) | Variables   | Level     |                   | First difference  |                   |                   |
|------------------------------------|-------------|-----------|-------------------|-------------------|-------------------|-------------------|
|                                    |             | intercept | Intercept & trend | intercept         | Intercept & trend |                   |
| South Asian countries              | lnEF        | 10.94     | 9.34              | 96.53*            | 77.83*            |                   |
|                                    | lnMF        | 2.64      | 53.04*            | 111.47*           | 88.08*            |                   |
|                                    | lnY         | 0.29      | 5.82              | 67.33*            | 65.71*            |                   |
|                                    | lnY2        | 0.2       | 4.34              | 62.47*            | 65.76*            |                   |
|                                    | lnEC        | 10.39     | 2.66              | 89.77*            | 83.39*            |                   |
|                                    | lnGI        | 15.5      | 17.8              | 96.46*            | 84.95*            |                   |
| East Asian countries               | lnUR        | 8.61      | 18.78***          | 5.58              | 54.55*            |                   |
|                                    | lnEF        | 2.9       | 17.75             | 43.42*            | 33.09*            |                   |
|                                    | lnMF        | 13.18     | 26.50*            | 53.81*            | 41.12*            |                   |
|                                    | lnY         | 4.41      | 9.08              | 42.72*            | 29.57*            |                   |
|                                    | lnY2        | 3.46      | 14.00***          | 42.68*            | 29.33*            |                   |
|                                    | lnEC        | 7.82      | 13.56***          | 42.41*            | 39.20*            |                   |
| Southeast Asian countries          | lnGI        | 25.09*    | 8.64              | 56.33*            | 53.78*            |                   |
|                                    | lnUR        | 8.3       | 15.37***          | 25.70*            | 23.99*            |                   |
|                                    | lnEF        | 29.93***  | 30.20***          | 152.22*           | 121.70*           |                   |
|                                    | lnMF        | 11.34     | 27.2              | 163.91*           | 122.36*           |                   |
|                                    | lnY         | 3.22      | 34.97**           | 83.55*            | 82.19*            |                   |
|                                    | lnY2        | 2.05      | 40.85*            | 82.95*            | 81.41*            |                   |
| Panel III: Phillips-Perron         | lnEC        | 25.67     | 40.92**           | 125.06*           | 108.98*           |                   |
|                                    | lnGI        | 50.19*    | 25.07             | 148.20*           | 124.87            |                   |
|                                    | lnUR        | 22.42     | 23.97             | 86.26*            | 63.94*            |                   |
|                                    | Whole panel | Variables | intercept         | Intercept & trend | intercept         | Intercept & trend |
|                                    | lnEF        | 84.74     | 118.00*           | 560.77*           | 844.05*           |                   |
|                                    | lnMF        | 110.02*   | 288.62*           | 687.64*           | 955.50*           |                   |
| West Asian countries               | lnY         | 61.19     | 163.71*           | 386.90*           | 419.39*           |                   |
|                                    | lnY2        | 53.49     | 178.14*           | 375.48            | 431.70*           |                   |
|                                    | lnEC        | 139.77*   | 313.28*           | 595.25*           | 881.53*           |                   |
|                                    | lnGI        | 222.4     | 88.02             | 545.75*           | 933.69            |                   |
|                                    | lnUR        | 192.09*   | 587.64*           | 87.68             | 302.79            |                   |
|                                    | lnEF        | 14.69     | 22.52             | 167.28*           | 223.21            |                   |
| Central Asian countries            | lnMF        | 30.64***  | 87.98*            | 142.04*           | 111.09*           |                   |
|                                    | lnY         | 18.11     | 11.35             | 100.05*           | 80.78*            |                   |
|                                    | lnY2        | 17.11     | 10.75             | 99.50*            | 80.29*            |                   |
|                                    | lnEC        | 24.13     | 17.68             | 182.44*           | 190.24*           |                   |
|                                    | lnGI        | 28.53     | 26.27             | 150.97*           | 185.04*           |                   |
|                                    | lnUR        | 15.8      | 294.42*           | 41.55*            | 278.54*           |                   |
| South Asian countries              | lnEF        | 33.23*    | 56.89*            | 87.44*            | 63.20*            |                   |
|                                    | lnMF        | 30.87*    | 73.42*            | 173.67*           | 456.85*           |                   |
|                                    | lnY         | 3.42      | 109.01*           | 73.36*            | 54.87*            |                   |
|                                    | lnY2        | 3.45      | 118.16*           | 74.89*            | 54.47*            |                   |
|                                    | lnEC        | 57.92*    | 235.14*           | 104.93*           | 335.24*           |                   |
|                                    | lnGI        | 56.59*    | 13.14             | 80.10*            | 77.23*            |                   |
| East Asian countries               | lnUR        | 49.47*    | 273.77*           | 28.45*            | 9.3               |                   |
|                                    | lnEF        | 11.77     | 9.28              | 97.12*            | 134.75*           |                   |
|                                    | lnMF        | 3.44      | 50.88*            | 117.82*           | 103.49*           |                   |
|                                    | lnY         | 0.27      | 4.14              | 73.22*            | 103.22*           |                   |
|                                    | lnY2        | 0.21      | 2.51              | 63.03*            | 102.24*           |                   |
|                                    | lnEC        | 10.86     | 2.37              | 90.20*            | 98.59*            |                   |
| Southeast Asian countries          | lnGI        | 20.36***  | 16.99             | 97.06*            | 336.39*           |                   |
|                                    | lnUR        | 64.27*    | 11.83             | 94.52*            | 33.18**           |                   |
|                                    | lnEF        | 2.44      | 8.11              | 53.80*            | 46.61*            |                   |
|                                    | lnMF        | 31.15*    | 33.95*            | 63.79*            | 52.56*            |                   |
|                                    | lnY         | 34.09*    | 10.63             | 44.76*            | 99.05*            |                   |
|                                    | lnY2        | 30.25*    | 9.75              | 44.65*            | 114.29*           |                   |
| Central Asian countries            | lnEC        | 26.25*    | 35.60*            | 46.69*            | 102.41*           |                   |
|                                    | lnGI        | 71.38*    | 8.45              | 65.45*            | 180.70*           |                   |
|                                    | lnUR        | 33.61*    | 6.7               | 25.18*            | 1.62              |                   |
|                                    | lnEF        | 22.58     | 21.18             | 155.10*           | 376.26*           |                   |
|                                    | lnMF        | 13.9      | 42.37*            | 190.31*           | 231.49*           |                   |
|                                    | lnY         | 5.28      | 28.56***          | 95.49*            | 81.45*            |                   |
| Southeast Asian countries          | lnY2        | 2.46      | 36.94**           | 93.39*            | 80.39*            |                   |
|                                    | lnEC        | 20.59     | 22.47             | 170.98*           | 155.04*           |                   |
|                                    | lnGI        | 45.52*    | 23.15             | 152.15*           | 154.31*           |                   |
|                                    | lnUR        | 89.13*    | 6.13              | 86.31*            | 63.31*            |                   |

\*, \*\* and \*\*\* Indicate the rejection of null of non-stationary and statistical significance at 1, 5 and 10 per cent level respectively.

Central-, South-, East and Southeast<sup>8</sup> Asian countries. It is evident from panel a of Tables 5 & 6 that calculated values of four out of seven tests were found to be greater than critical values hence it reject the null of no cointegration at 1, 5 and 10% level of significance. Similarly the lower panel of Tables 5 & 6 shows ADF based statistics from Kao (1999) panel cointegration test. It also rejects the null of no cointegration and hence validating the existence of cointegration among the considered variables. Thus, it can be concluded that EF, economic growth, square of economic growth, energy consumption, urbanization, and globalization are cointegrated in the long run. And similarly MF are cointegrated with same covariates. Now we can proceed for long- and short-run coefficient estimation and analyse the effect of considered variables on the EF and MF.

#### 4.3. Long run estimates

Finally, the long-run elasticities of covariates on EF and MF can be meaningfully derived as cointegration is established. For this purpose, PMG, DOLS, and GMM estimator has been applied. PMG results for whole panel and sub-panel group given in Table 7. In case of whole panel of Asian countries, it show positive impact of GDP on the EF while its square term turn to be negative. Hence it evident that after reaching certain threshold level of income, EF tends to decline as advocated by the EKC hypothesis. While in case of sub-panel, only Central and East Asia follows similar results. This association between economic growth and EF is consistent with the studies like Ulucak and Bilgili (2018), and Fakher (2019). On the contrary West, South and Southeast Asian panel shows that economic growth (the square of economic growth) is negative (positive) i.e.  $\beta_{2i} < 0$  and  $\beta_{1i} > 0$ . Hence contrary to EKC of “inverted U shape” the results depicts a U shaped association with the ecological footprint (EF). This findings is in line with those of Bagliani et al. (2008), Pablo-Romero and Sanchez-Braza (2017). It may be due to inefficient production system that does not take care of environmental impact. Hence at initial stage, they starts utilizing its idle capacity and lying natural resources and after that it causing environmental damage.

Coming to the other covariates, PMG results reported in Table 7, reveals energy consumption bear significant positive impact on EF for all different panels of countries. This positive relationship between energy consumption and ecological footprint is consistent with many studies like Ahmed et al. (2019), Charfeddine and Mrabet (2017) and Mrabet and Alsamara (2017). Demand of energy, particular fossil-fuel, is increasing in these developing countries which cause huge environmental pollution hence it require great attention (Liu et al., 2007; Destek et al., 2018). In addition, it was observed that globalization on average is positive and significant hence it increases the environmental pressure across Asian countries. This association is expected as globalization can directly impact growth through increased trade, foreign direct investment and total factor productivity while indirectly it also give rise to carbon emissions with higher consumption of energy. In other words, in the developing countries globalizations give rise to pollution industries where weak environmental policy exists (Copeland and Taylor, 2004). As mentioned earlier there are different classifications of globalization (social, political and economic) it can have direct impact of pollution in which human being coexists. The studies like Shahbaz et al. (2013) and Frankel (2003) supported that the globalization have a positive impact on ecological footprint. By taking KOF globalization Shahbaz et al. (2017) analyzed the effect of globalization on ecological footprint in China and observed that globalization is good for China. The empirical finding further show that globalization does

<sup>8</sup> Pedroni cointegration test in the case of Southeast Asian countries show that out of 7 test statistics only 3 tests is rejected the null of no cointegration. Still there is evidence of cointegration in the long run; this is because these three test statistics are the mixture of parametric and non-parametric approach which is assumed to be good.

**Table 5**  
Panel Cointegration Test with EF.

a) Pedroni test  $EF = f(Y, Y, EC, GI, UR)$

| Common AR coeffs. (within-dimension) | Whole panel |       | West Asia |        | Central Asia |        | South Asia |       | East Asia |         | Southeast Asia |       |
|--------------------------------------|-------------|-------|-----------|--------|--------------|--------|------------|-------|-----------|---------|----------------|-------|
|                                      | Statistic   | Prob. | Statistic | Prob.  | Statistic    | Prob.  | Statistic  | Prob. | Statistic | Prob.   | Statistic      | Prob. |
| Panel v-Statistic                    | -1.64       | 0.95  | -0.89     | 0.81   | 0.62         | 0.26   | -0.12      | 0.55  | 0.46      | 0.03**  | -3.69          | 0.99  |
| Panel rho-Statistic                  | 2.29        | 0.98  | 1.99      | 0.97   | 0.10         | 0.54   | 1.31       | 0.90  | 0.51      | 0.69    | 4.41           | 1.00  |
| Panel PP-Statistic                   | -3.83       | 0.00* | -2.21     | 0.01** | -3.16        | 0.00*  | -2.35      | 0.00* | 0.33      | 0.06*** | 1.64           | 0.95  |
| Panel ADF-Statistic                  | -6.11       | 0.00* | -3.61     | 0.00*  | -2.43        | 0.00*  | -3.75      | 0.00* | -3.69     | 0.00*   | -3.33          | 0.00* |
| Group rho-Statistic                  | 4.09        | 1.00  | 2.81      | 0.99   | 1.24         | 0.89   | 2.14       | 0.98  | 1.23      | 0.89    | 4.35           | 1.00  |
| Group PP-Statistic                   | -4.20       | 0.00* | -5.53     | 0.00*  | -1.81        | 0.03** | -2.73      | 0.00* | 0.56      | 0.71    | -4.55          | 0.00* |
| Group ADF-Statistic                  | -5.91       | 0.00* | -4.50     | 0.00*  | -3.48        | 0.00*  | -3.94      | 0.00* | -4.75     | 0.00*   | -3.00          | 0.00* |
| b) Kao test                          | Whole panel |       | West Asia |        | Central Asia |        | South Asia |       | East Asia |         | Southeast Asia |       |
| ADF                                  | t-Value     | Prob. | t-Value   | Prob.  | t-Value      | Prob.  | t-Value    | Prob. | t-Value   | Prob.   | t-Value        | Prob. |
|                                      | 0.15        | 0.00* | -3.83     | 0.00*  | -7.08        | 0.00*  | -2.47      | 0.00* | -3.28     | 0.00*   | -3.22          | 0.00* |

\*, \*\* and \*\*\* Indicate the rejection of null no cointegration and is statistically significance at 1, 5 and 10 per cent level respectively.

**Table 6**  
Panel Cointegration Test with MF.

Panel a: Pedroni cointegration test  $MF = f(Y, Y^2, EC, GI, UR)$

| Common AR coeffs. (within-dimension)      | Whole panel |        | West Asia   |        | Central Asia |        | South Asia  |       | East Asia   |         | Southeast Asia |       |
|-------------------------------------------|-------------|--------|-------------|--------|--------------|--------|-------------|-------|-------------|---------|----------------|-------|
|                                           | Statistic   | Prob.  | Statistic   | Prob.  | Statistic    | Prob.  | Statistic   | Prob. | Statistic   | Prob.   | Statistic      | Prob. |
| Panel v-Statistic                         | 1.98        | 0.02** | -0.61       | 0.73   | 2.30         | 0.01** | 3.25        | 0.00* | 1.76        | 0.03**  | 2.69           | 0.00* |
| Panel rho-Statistic                       | -0.50       | 0.30   | 2.16        | 0.98   | -1.78        | 0.03** | -0.01       | 0.49  | -1.30       | 0.09*** | -0.19          | 0.42  |
| Panel PP-Statistic                        | -10.92      | 0.00*  | -2.32       | 0.01** | -7.58        | 0.00*  | -4.73       | 0.00* | -6.02       | 0.00*   | -6.22          | 0.00* |
| Panel ADF-Statistic                       | -9.53       | 0.00*  | -2.30       | 0.01** | -6.41        | 0.00*  | -4.80       | 0.00* | -6.58       | 0.00*   | -6.14          | 0.00* |
| Individual AR coeffs. (between-dimension) | Statistic   | Prob.  | Statistic   | Prob.  | Statistic    | Prob.  | Statistic   | Prob. | Statistic   | Prob.   | Statistic      | Prob. |
| Group rho-Statistic                       | 2.44        | 0.99   | 2.34        | 0.99   | -0.28        | 0.38   | 1.43        | 0.92  | 0.47        | 0.68    | 1.15           | 0.87  |
| Group PP-Statistic                        | -9.22       | 0.00*  | -5.60       | 0.00*  | -7.02        | 0.00*  | -3.28       | 0.00* | -3.62       | 0.00*   | -5.33          | 0.00* |
| Group ADF-Statistic                       | -8.72       | 0.00   | -3.26       | 0.00*  | -6.12        | 0.00*  | -3.47       | 0.00* | -4.51       | 0.00*   | -5.65          | 0.00* |
| Panel: b Kao test                         | Whole panel |        | West Asia   |        | Central Asia |        | South Asia  |       | East Asia   |         | Southeast Asia |       |
| ADF                                       | t-Statistic | Prob.  | t-Statistic | Prob.  | t-Statistic  | Prob.  | t-Statistic | Prob. | t-Statistic | Prob.   | t-Statistic    | Prob. |
|                                           | -2.67       | 0.00*  | -7.34       | 0.00*  | -5.73        | 0.00*  | -7.51       | 0.00* | -2.61       | 0.00*   | -2.73          | 0.00* |

\*, \*\* and \*\*\* Indicate the rejection of null no cointegration and is statistically significance at 1, 5 and 10 per cent level respectively.

**Table 7**  
Pooled Mean Group Results (Dependent variable-Ecological footprint).

Panel a: Long-run Estimates

| Variables                    | Whole panel |         | West Asia   |         | Central Asia |         | South Asia  |         | East Asia   |         | Southeast Asia |         |
|------------------------------|-------------|---------|-------------|---------|--------------|---------|-------------|---------|-------------|---------|----------------|---------|
|                              | Coefficient | P value | Coefficient | P value | Coefficient  | P value | Coefficient | P value | Coefficient | P value | Coefficient    | P value |
| lnY                          | 0.75        | 0.00*   | -4.14       | 0.00*   | 2.03         | 0.00*   | -0.69       | 0.00*   | 6.75        | 0.00*   | -2.57          | 0.00*   |
| lnY <sup>2</sup>             | -0.04       | 0.00*   | 0.26        | 0.00*   | -0.10        | 0.00*   | 0.05        | 0.00*   | -0.31       | 0.00*   | 0.20           | 0.00*   |
| lnEC                         | 0.12        | 0.00*   | 0.31        | 0.00*   | 0.96         | 0.00*   | 0.30        | 0.00*   | 0.37        | 0.00*   | 0.09           | 0.00*   |
| lnGI                         | 0.19        | 0.00*   | 0.74        | 0.00*   | 0.01         | 0.94    | 0.14        | 0.00*   | -0.98       | 0.00*   | 0.26           | 0.00*   |
| lnUR                         | -0.08       | 0.50    | 0.002       | 0.00*   | -0.24        | 0.00*   | -0.01       | 0.00*   | 0.002       | 0.10    | 1.17           | 0.00*   |
| Panel b: Short Run Estimates |             |         |             |         |              |         |             |         |             |         |                |         |
| Error correction             | -0.27       | 0.00*   | -0.76       | 0.02**  | -0.27        | 0.03**  | -0.70       | 0.02**  | -0.58       | 0.00*   | -0.59          | 0.00*   |
| D(lnY)                       | -2.33       | 0.67    | 47.11       | 0.33    | -0.00        | 0.99    | -5.86       | 0.47    | -29.64      | 0.16    | -9.15          | 0.57    |
| D(lnY <sup>2</sup> )         | 0.21        | 0.47    | -2.10       | 0.40    | -0.04        | 0.87    | 0.46        | 0.44    | 1.73        | 0.15    | 0.52           | 0.49    |
| D(lnEC)                      | 0.11        | 0.64    | 0.40        | 0.02**  | 0.08         | 0.52    | 0.49        | 0.00*   | -1.13       | 0.33    | 0.09           | 0.33    |
| D(lnGI)                      | -0.16       | 0.31    | 0.77        | 0.43    | -0.37        | 0.01**  | 0.44        | 0.44    | -2.57       | 0.39    | -0.37          | 0.43    |
| D(lnUR)                      |             |         | 3.33        | 0.29    | -0.34        | 0.16    | 0.95        | 0.55    | -0.03       | 0.70    |                |         |
| D(lnUR-1)                    |             |         | -3.20       | 0.21    |              |         | -2.37       | 0.41    | -0.13       | 0.42    |                |         |
| Obs.                         | 925         |         | 220         |         | 182          |         | 138         |         | 100         |         | 250            |         |
| Log likelihood               | 1702.67     |         | 553.35      |         | 295.89       |         | 362.78      |         | 180.07      |         | 547.98         |         |

\*, \*\* and \*\*\* Indicate the statistical significance at 1, 5 and 10 per cent level respectively.

not have significant impact on EF<sup>9</sup> in the case of central Asian panel. This may be due to these countries unable to make appreciable and effective use of globalization by importing advanced technology in

enhancing their performance to reduce ecological footprint (environmental damage). Whereas globalization is found to be negative and significant in case of East Asian panel. This finding is in conformity with studies like Charfeddine and Mrabet (2017) and Shahbaz et al. (2016). Hence contrary to overall results East Asian countries effectively use foreign investment and technical know-how to reduce its ecological

<sup>9</sup> This study is in line with Ahmed et al. (2019) reveals globalization is not a significant determinant of the EF

**Table 8**  
Pooled Mean Group Results (Dependent variable-Material footprint).

| Panel a: Long Run Equation  |             |         |             |         |              |         |             |         |             |         |                |         |
|-----------------------------|-------------|---------|-------------|---------|--------------|---------|-------------|---------|-------------|---------|----------------|---------|
| Variables                   | Asian panel |         | West Asia   |         | Central Asia |         | South Asia  |         | East Asia   |         | Southeast Asia |         |
|                             | Coefficient | P value | Coefficient | P value | Coefficient  | P value | Coefficient | P value | Coefficient | P value | Coefficient    | P value |
| lnY                         | 2.16        | 0.00*   | 2.93        | 0.05**  | −2.97        | 0.00*   | 4.29        | 0.00*   | 1.76        | 0.01**  | 3.89           | 0.00*   |
| lnY2                        | −0.16       | 0.00*   | −0.20       | 0.00*   | 0.41         | 0.00*   | −0.36       | 0.00*   | −0.13       | 0.00*   | −0.40          | 0.00*   |
| lnEC                        | 0.20        | 0.00*   | 1.20        | 0.00*   | 0.47         | 0.00*   | 0.88        | 0.01**  | 0.31        | 0.00*   | 0.60           | 0.00*   |
| lnGI                        | 2.66        | 0.00*   | 4.46        | 0.00*   | 1.63         | 0.00*   | 0.06        | 0.94    | −0.30       | 0.00*   | −1.09          | 0.00*   |
| lnUR                        | 0.28        | 0.00*   | 0.03        | 0.00*   | 0.03         | 0.47    | 0.11        | 0.01**  | −0.003      | 0.02**  | 0.08           | 0.00*   |
| Panel b: Short Run Equation |             |         |             |         |              |         |             |         |             |         |                |         |
| Error correction            | −0.05       | 0.00*   | −0.14       | 0.09*** | −0.32        | 0.02**  | −0.13       | 0.00*   | −0.78       | 0.05**  | −0.22          | 0.00*   |
| D(lnY)                      | 23.24       | 0.04**  | 40.17       | 0.21    | 1.15         | 0.53    | 4.01        | 0.32    | 27.50       | 0.5     | −7.99          | 0.73    |
| D(lnY2)                     | −1.10       | 0.05**  | −2.19       | 0.19    | −0.08        | 0.49    | −0.26       | 0.39    | −1.03       | 0.65    | 0.23           | 0.84    |
| D(lnEC)                     | 0.05        | 0.61    | −0.23       | 0.32    | 0.28         | 0.33    | −0.02       | 0.83    | 0.07        | 0.70    | −0.01          | 0.86    |
| D(lnGI)                     | −0.43       | 0.01**  | −1.10       | 0.05*** | −0.46        | 0.01**  | −0.18       | 0.40    | −0.20       | 0.61    | 0.04           | 0.85    |
| D(lnUR)                     | 1.01        | 0.31    | 3.33        | 0.07*** | −0.35        | 0.38    | −0.36       | 0.08*** | 0.11        | 0.08*** | 1.11           | 0.81    |
| Obs.                        | 962         |         | 240         |         | 175          |         | 138         |         | 96          |         | 250            |         |
| Log likelihood              | 1128.24     |         | 549.33      |         | 245.41       |         | 255.55      |         | 199.98      |         | 438.42         |         |

\*, \*\* and \*\*\* Indicate the statistical significance at 1, 5 and 10 per cent level respectively.

burden. Finally, urbanisation overall does not having statistically significant impact on EF. While in case of sub-panel it seems to have significant impact, it has positive coefficient in case of west, east and southeast Asian panel<sup>10</sup>, and shows in these countries urbanisation has intensify economic activities and ecological damage. Contrary to this, central and south Asian panel have negative coefficient which depict urbanisation leads to efficiency and agglomeration effect.

The study also employed DOLS and GMM method to estimates log-run coefficient for the robustness purposes. The coefficient of covariates of EF reported in Appendix Table A1 and A2. The overall results of DOLS and GMM are similar to that of PMG, however, compared to PMG, magnitude of coefficients differ among the variables. The DOLS results for the Central-and East Asian countries indicate the validation of environmental Kuznets curve (EKC) hypothesis in both these Asian panels. Moreover, it was revealed that energy use is the main sources of carbon emissions (environmental damage) hence it has positive effect on EF. Furthermore, the effect of globalization on EF is positive and negative in Central and East Asian panel respectively.

We have also applied MF as an indicator of resource efficiency and environmental pressure, the long-run coefficients of estimated PMG model has been given in Table 8. The coefficient of GDP is positive meaning that economic growth require higher level of material except for central Asian panel. While the negative sign of square term of GDP supports the inverted U-shape relationship, so after certain threshold level, MF reduces. It means EKC hypothesis hold for all panel except in case of central Asian panel. Overall similar results have been found in case of EF. However using MF indicator show relatively more in favor of EKC whereas in case of EF only two sub-panel; Central and East Asian. Energy consumption bear positive and significant coefficient with MF across different panels of Asian countries. It seems complementarity between energy consumption and MF as both are crucial inputs in the production. Whereas impact of globalization is mixed, overall, coefficient of whole panel is positive along with west and central Asian panel. While in case of east and southeast globalization has negative coefficient means it enhances resource efficiency for these countries. Moving to less-material intensive or service sector also reduced domestic as well as importing materials for final production activities. Further in case of urbanization, though magnitude are less, it has significant effect on MF indicator. Overall, the results support that urbanization leads to higher material requirement. Similar results were also reported by Teixidó-Figueras et al. (2016) using material footprint as an indicator of environmental degradation. We have also applied alternative estimator of finding

drivers of MF indicator, the coefficient of covariates from DOLS and GMM are reported in Appendix Table A3 and A4. The overall results of DOLS and GMM are similar to that of PMG, however, compared to PMG, there are some differences in statistical significance and magnitude of coefficients.

Asian countries are in developing stage hence it demands greater resource for infrastructure and industrial activities. It also undergoing to structural changes from agricultural to industry and moving to service sector. Hence greater effort is required for making sustainable use of ecological resources. Most countries have increasing population level which require more resources and hence undermine the damage to the environmental resources. These countries needs to properly harness the benefits from globalized world to enhance its efficiency. While process of urbanization needs to assessed and policy initiative required for achieving economies of scale and resource conservation. Both managerial and technical efforts should be putted for getting benefits from urban agglomeration of industries and societies. Further the preference of society for the importance of ecological conservation needs to be developed. Demand-based forces works for pressuring major sources of emission to install emission reduction technology. Since industries are major sources of emission, it is essential to adopt an eco-friendly operation with advanced cost-effective measures (Haider et al., 2019a). It is further suggested that Asian countries should follows the developed countries for conservational of natural resources. It should adopt eco-friendly management of urban space and resources (Haider and Adil, 2019; Haider et al., 2019b). While materials and energy efficiency should be enhance with better technology and cross-border investment in efficiency enhancement project (Haider and Akram, 2019; Haider and Mishra, 2019).

Moreover, Asia is well-off in mineral resources having enormous potential from powerful sunlight, tidal and wave power to sizeable hydropower and geothermal resources, wind in the center latitudes. South Korea, in particular in a developing stage of tidal and wave resource. Japan has substantial geothermal sector whereas China has considerable solar and wind energy. Natural resource vary from country to country, still there is need to understand that consumption of renewable energy source mostly remained untapped in Asia. According to the survey conducted by world energy resources 2010, it was observed that globally 15.5 GW geothermal capacity were installed out of which 4.55 GW were planted in Asia. Globally, 327 GW wind were installed out of which 87.4 GW were installed in Asia. Europe were the primary manufacturer of solar energy followed by Asia generated 11.5 GW, on the other hand, leading producer of hydropower is China which produce 61.4 (Mtoe)<sup>11</sup> annually.

<sup>10</sup> Similar results were also reported by Zhang (2019) in the case of Central Asia.

<sup>11</sup> Millions tons of oil equivalent.

## 5. Conclusion and policy implications

Previous literatures have the major weakness in extensive use of CO<sub>2</sub> emissions as an indicator of environmental damage, which comprises only a small segment of entire environmental pollution. They have estimated the environmental Kuznets curve hypothesis which may be inappropriate for deriving policies for broader set of ecological degradation. As a consequence, recent literature emphasize on a more inclusive measure on environmental damage hence utilize ecological footprint for purpose. Therefore, the main objective of this empirical study is to investigate the EKC hypothesis by using ecological footprint and material footprint indicators. The sample includes different panels of thirty-seven Asian countries. Asian sub-regions includes West Asia-, Central Asia-, South Asia-, East Asia- and Southeast Asian countries. Panel data model has been applied for the empirical analysis particularly PMG, DOLS and dynamic GMM have been applied for long-run coefficient estimation. Overall results supports the existence of EKC for EF and MF. While Mix results are found in case of sub-panels, there exhibits U-shaped relationship between economic growth and ecological footprint for West-, South- and Southeast Asian countries. However, for Central- and East Asian panels, EKC hypothesis is found to be valid. One of the reasons could be the fact that for West-, South- and Southeast Asian countries, level of economic development are in the relatively growing phase. The existence of EKC depends upon the availability of better technology, renewable energy, energy saving and efficiency. Asian countries needs institutional and policy support for technology transfer from developed countries.

Energy consumption leads to higher level of EF and MF requirement, as it has significant positive impact on EF and MF for all different panels of countries. In addition, it was observed that globalization on average drive to greater requirement and ecological and materials resources. Hence it increases the environmental pressure across Asian countries. Whereas globalization brought significant reduction of EF and MF in case of East Asian panel. Hence contrary to overall results East Asian countries effectively use foreign investment and technical know-how to reduce its ecological burden. Finally, urbanisation effect seems to be neutral and it does not statistically significant impact EF. While significant impact is observed in case of MF. In case of west, east and southeast Asian panel, urbanisation has intensify economic

activities and ecological damage. Contrary to this, central and south Asian panel have negative coefficient which depict urbanisation leads to efficiency and agglomeration effect.

For making an inverted U-turn in the EKC practically, still much more is needed for sustainable development goals and meeting the Paris agreement especially in West-, South-, and Southeast Asian countries. This can be achieved by; (i) Increasing energy independence and energy security, (ii) reducing environmental pollution and providing access to modern energy for these countries, (iii) decreasing the demand for energy consumption in all sectors by 2030, (iv) reducing the non-renewable energy consumption, in particular oil and coal and at the same time increasing the usage of renewable energy source, (v) sufficient financial device such as incentives, grants, removal of barriers require the development to speed up the investment to boost renewable energy sector. Lastly, for achieving Paris agreement goal, removal of subsidies and carbon pricing model play an important role in retaining sustainable development objectives. In facilitating development of renewable energy, feed in tariff have already proven to be effective (REN21, 2018). Harnessing efficiency and economies effect of Urbanization and globalization will be instrumental are require policy attention.

## CRedit authorship contribution statement

**Mohd Arshad Ansari:** Conceptualization, Methodology, Writing - original draft. **Salman Haider:** Data curation, Writing - review & editing, Software. **N.A. Khan:** Supervision, Resources.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgement

Author(s) are thankful to two anonymous referees for their valuable comments that improves the quality of the paper. Usual disclaimer hold.

## Appendix

**Table A1**  
Dynamic OLS Results (Dependent variable-Ecological footprint).

|          | Asian panel |         | West Asia   |         | Central Asia |         | South Asia  |         | East Asia   |         | Southeast Asia |         |
|----------|-------------|---------|-------------|---------|--------------|---------|-------------|---------|-------------|---------|----------------|---------|
|          | Coefficient | P value | Coefficient | P value | Coefficient  | P value | Coefficient | P value | Coefficient | P value | Coefficient    | P value |
| lnY      | 0.85        | 0.00*   | −1.09       | 0.00*   | 1.05         | 0.00*   | −2.79       | 0.00*   | 8.62        | 0.04**  | −0.73          | 0.06*** |
| lnY2     | −0.05       | 0.00*   | 0.07        | 0.00*   | −0.05        | 0.00*   | 0.22        | 0.00*   | −0.42       | 0.07*** | 0.07           | 0.00*   |
| lnEC     | 0.45        | 0.00*   | 0.25        | 0.00*   | 0.50         | 0.00*   | 0.11        | 0.00*   | 1.25        | 0.00*   | 0.12           | 0.00*   |
| lnGI     | 0.05        | 0.09*** | 0.55        | 0.00*   | 1.09         | 0.00*   | 0.47        | 0.00*   | −3.06       | 0.00*   | 0.15           | 0.09*** |
| lnUR     | −0.001      | 0.20    | 0.007       | 0.00*   | −0.01        | 0.00*   | −0.02       | 0.00*   | 0.02        | 0.44    | 0.01           | 0.05**  |
| R square | 0.91        |         | 0.90        |         | 0.99         |         | 0.99        |         | 0.57        |         | 0.99           |         |
| Obs.     | 999         |         | 270         |         | 170          |         | 146         |         | 96          |         | 270            |         |

\*, \*\* and \*\*\* Indicate the statistical significance at 1, 5 and 10 per cent level respectively.



**Table A2**  
GMM Results Arellano–Bond estimations: (Dependent variable-Ecological footprint).

|             | Asian panel |         | West Asia   |         | Central Asia |         | South Asia  |         | East Asia   |         | Southeast Asia |         |
|-------------|-------------|---------|-------------|---------|--------------|---------|-------------|---------|-------------|---------|----------------|---------|
|             | Coefficient | P value | Coefficient | P value | Coefficient  | P value | Coefficient | P value | Coefficient | P value | Coefficient    | P value |
| lnY         | 0.565       | 0.00*   | −0.880      | 0.00*   | 1.568        | 0.01*   | −1.240      | 0.01*   | 2.125       | 0.03**  | −0.556         | 0.08*** |
| lnY2        | −0.031      | 0.02*   | 0.060       | 0.03*   | −0.092       | 0.00*   | 0.178       | 0.00*   | −0.549      | 0.07*** | 0.037          | 0.01*   |
| lnEC        | 0.781       | 0.02*   | 0.789       | 0.01*   | 0.422        | 0.03*   | 0.217       | 0.02*   | 1.068       | 0.00*   | 0.209          | 0.00*   |
| lnGI        | 0.023       | 0.07*** | 0.468       | 0.09*   | 0.439        | 0.00*   | 0.569       | 0.00*   | −1.174      | 0.01*   | 0.087          | 0.09*** |
| lnUR        | −0.022      | 0.177   | 0.013       | 0.00*   | −0.122       | 0.170   | −0.055      | 0.140   | 0.087       | 0.180   | 0.083          | 0.05**  |
| F-test      | 299.120     | 0.00*   | 198.210     | 0.00*   | 457.870      | 0.00*   | 563.320     | 0.00*   | 183.870     | 0.00*   | 376.110        | 0.00*   |
| AR(2) Test  | −0.230      | 0.110   | −0.560      | 0.210   | −0.760       | 0.310   | −0.480      | 0.281   | −0.870      | 0.531   | −0.640         | 0.271   |
| Sargan test | 1.270       | 0.680   | 1.670       | 0.650   | 1.340        | 0.460   | 1.690       | 0.450   | 1.980       | 0.930   | 1.880          | 0.340   |

**Table A3**  
Dynamic OLS Results (Dependent variable-Material footprint).

| Variables | Asian panel |         | West Asia   |         | Central Asia |         | South Asia  |         | East Asia   |         | Southeast Asia |         |
|-----------|-------------|---------|-------------|---------|--------------|---------|-------------|---------|-------------|---------|----------------|---------|
|           | Coefficient | P value | Coefficient | P value | Coefficient  | P value | Coefficient | P value | Coefficient | P value | Coefficient    | P value |
| lnY       | 0.95        | 0.00*   | 1.81        | 0.04**  | −2.42        | 0.00*   | 4.03        | 0.01**  | 3.64        | 0.00*   | 1.30           | 0.00*   |
| lnY2      | −0.03       | 0.09*** | −0.09       | 0.01**  | 0.14         | 0.00*   | −0.35       | 0.00*   | −0.14       | 0.00*   | −0.18          | 0.00*   |
| lnEC      | 0.20        | 0.00*   | 0.60        | 0.06*** | 0.46         | 0.00*   | 0.38        | 0.01**  | 0.56        | 0.00*   | 0.83           | 0.00*   |
| lnGI      | 0.36        | 0.00*   | 1.90        | 0.04**  | 0.76         | 0.00*   | 0.79        | 0.72    | −3.24       | 0.00*   | −1.01          | 0.00*   |
| lnUR      | 0.01        | 0.00*   | 0.05        | 0.23    | 0.007        | 0.66    | 0.10        | 0.00*   | −0.02       | 0.00*   | 0.69           | 0.00*   |
| R square  | 0.99        |         | 0.96        |         | 0.92         |         | 0.72        |         | 0.99        |         | 0.99           |         |
| Obs.      | 999         |         | 240         |         | 189          |         | 162         |         | 96          |         | 240            |         |

\*, \*\* and \*\*\* Indicate the statistical significance at 1, 5 and 10 per cent level respectively.

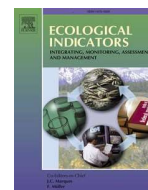
**Table A4**  
GMM Results Arellano–Bond estimations: (Dependent variable-Material footprint).

|             | Asian panel |         | West Asia   |         | Central Asia |         | South Asia  |         | East Asia   |         | Southeast Asia |         |
|-------------|-------------|---------|-------------|---------|--------------|---------|-------------|---------|-------------|---------|----------------|---------|
|             | Coefficient | P value | Coefficient | P value | Coefficient  | P value | Coefficient | P value | Coefficient | P value | Coefficient    | P value |
| lnY         | 0.373       | 0.00*   | 1.365       | 0.05**  | 1.044        | 0.01*   | 1.956       | 0.02**  | 2.464       | 0.00*   | 2.594          | 0.00*   |
| lnY2        | −0.079      | 0.07*** | −0.050      | 0.02**  | −0.271       | 0.00*   | −0.201      | 0.00*   | −0.163      | 0.00*   | −0.496         | 0.00*   |
| lnEC        | 0.883       | 0.01*   | 0.340       | 0.08*** | 0.493        | 0.00*   | 0.476       | 0.01**  | 0.313       | 0.00*   | 0.310          | 0.00*   |
| lnGI        | 0.471       | 0.02*   | 1.743       | 0.210   | 0.406        | 0.01*   | 0.124       | 0.320   | −1.138      | 0.00*   | −1.602         | 0.00*   |
| lnUR        | 0.091       | 0.00*   | 0.046       | 0.230   | 0.029        | 0.160   | 0.702       | 0.00*   | −0.086      | 0.00*   | 0.342          | 0.230   |
| F-test      | 239.120     | 0.01*   | 118.210     | 0.00*   | 177.870      | 0.02*   | 765.120     | 0.00*   | 123.870     | 0.00*   | 276.110        | 0.00*   |
| AR(2) Test  | −0.860      | 0.180   | −0.640      | 0.270   | −0.680       | 0.360   | −0.550      | 0.316   | −0.765      | 0.270   | −0.780         | 0.198   |
| Sargan test | 1.230       | 0.610   | 1.190       | 0.510   | 0.881        | 0.360   | 1.310       | 0.650   | 1.470       | 0.850   | 1.610          | 0.680   |

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# Decomposing the trade-environment nexus for high income, upper and lower middle income countries: What do the composition, scale, and technique effect indicate?

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## ARTICLE INFO

### JEL classifications:

F18  
O44  
Q2  
Q37  
Q54

### Keywords:

Ecological footprint  
Economic growth  
Trade openness  
Scale effect  
Composition effect  
Technique effect  
Cross sectional dependence  
Heterogeneity

## ABSTRACT

This study empirically examines the impact of trade openness on ecological footprint ( $F$ ) employing panel data time series covering the period 1991–2016 for the sample of thirty five Asian countries. To analyze the consequence of trade at three distinct transition points, we decompose the trade effect into scale, composition, and technique effects. Using second generation econometric approaches that considers the issue of cross sectional dependence, the result show positive (negative) effect of scale (technique) on ecological footprint which validates the environmental Kuznets curve hypothesis for high income, upper middle and lower middle income countries. Further, energy consumption contribute to ecological footprint whereas, composition effect and trade openness mitigates environmental degradation. However, the results vary across different sub-panels. The findings impart innovative approach to detect the influence of trade openness in three sub dimensions of trade liberalization. Hence, for trade policy makers and economists, this article assigns more comprehensive policy implications and suggest sustainable trade agreements among the region.

## 1. Introduction

Today, developed nations is in favour of opening economies as well as for more trade openness, as export and import has positive impact on country's growth. This changing pattern of trade has started the debate that more openness in trade may cause environmental improvement globally. Following standard Stolper-Smuelson model of trade, all firms would shift to less-pollution-intensive good techniques and price paid for using environment would be bid up. Yet, following the Heckscher-Ohlin theorem, a country would be relatively environment abundant with having low factor price ratio. There would be a specialization in the pollution intensive products because of the trade openness and there would be no change in the overall use of environment in the Heckscher-Ohlin model of trade (Baek et al., 2009; Managi et al., 2009; Halicioglu, 2009; Khalil and Inam, 2006). The openness in trade has statistically significant effect on environmental quality was first carried out by Grossman and Krueger (1991). The promoters of trade openness claims

that trade encourage economic activity and liable to deterioration of environmental quality if the methods of production remains unchanged. The proponents of trade openness suppose that if environmental quality treated as normal product due to relax environment regulation then firms in less developed economies will move from high to low standard of production techniques and this action may affect the income distribution at global level. On the other hand, oppositions of trade openness claim that the country discourage the use of outdated and old methods of production and presumes trade improves the quality of environment and economy as whole. The authorities treat quality of environment as normal good and demand clean environment, as the level of traded income rises. Since developed nations enforce harsh environmental regulations, trade openness increases pollution intensive goods in developing countries thereby having adverse impact on the quality of environment (Copeland, 2005; Ahmed et al., 2019; Nabavi-Pesarsaei et al., 2017).

Although theoretical association between quality of environmental

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<https://doi.org/10.1016/j.ecolind.2020.107122>

Received 22 May 2020; Received in revised form 6 September 2020; Accepted 22 October 2020

Available online 2 November 2020

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and trade openness is not clear, but as its structure of comparative advantage changes, firms in developed countries raised the issues over dirty production of goods to less developing countries. Firms in developing nations have to face less stringent environment as compared to advance nations and are more concerned that liberalization in international trade will encourage the production of dirty industries, thus causing serious concern over environmental problems to the country (Dean, 2002; Laspidou et al., 2020). The present globe is now split into trade openness and trade blocks likely to affect not only the quality of environment enjoyed by all the states of the country but also socio-economic well-being of the countries in trade blocks; such that environmental problem on one hand, trade relationship on the other is widely accepted and well established (Baylis, 2005; McArthur and Sachs, 2001).

There is a plenty of research that empirically test trade-pollution relationship; however, the results have been contradictory (Ahmed, 2014; Ahmed et al., 2019; Nosratabadi et al., 2019; Mostashari-Rad et al., 2019; Jafari-Sejathrood et al., 2019). For instance: Frankel and Rose (2005) analyze the relationship between environment and trade and found negative impact of trade openness on carbon dioxide (CO<sub>2</sub>) emissions, but the later studies of Managi et al. (2009) explores that the effect of trade on environment depends upon the pollutants and economic structure of the country. Their study further analyze country specific effect and finds trade detriments CO<sub>2</sub> emissions with highest concentration in Malaysia. Managi (2004) investigated the association among trade-environment nexus and showed positive effect of trade on emissions for both developed and developing nations. The recent empirical studies of Ling et al. (2015) and Sbia et al. (2014) state that trade-emissions consequences may also differ because of scale, composition and technique effects. However, the study also assessed their theoretical statement and points out several indicators that influence Asia's emissions. For example; the findings of Chandran and Tang (2013) conclude that consumption of energy significantly contribute to environmental pollution in Asia's five emerging countries, Liu et al. (2017) showed that consumption of non-renewable energy causes emissions both in short and long run, Sabir and Gorus (2019) conclude that globalization also cause environmental damage in South Asia, and Zhang (2019) conclude that urbanization showed positive impact on emissions. However, there has been mixed results in the case of Asia on the association between trade and environment quality. Ahmed et al. (2019) found that trade openness are highly emissions intensive and are major contributor to pollution in case of 8 developing countries of Asia, whereas Ansari et al. (2019) conclude that Asia's trade have negative correlation with environmental degradation. Although abundant empirical work has examined the development-emission nexus in case of Asia, further empirical investigations is required on the profile of country's emissions due to involvement of various other development indicators. The simultaneous growth in institutional quality and technology on which the liberalization of trade is mainly depends on. In recent years pollution has become a serious concern in Asian countries especially in China, India and Japan are the top three Asian nations with largest amount of carbon emissions. Hence, Asian countries requires substantial investment in infrastructure development and energy resources in order to use effective use of regional resources which allows to decelerate global carbon emissions and improve the energy efficiency rate. Hence whether Asian countries has potential to achieve sustainable development economy is still remained unanswered. This empirical paper examines the effect of trade on environmental pollution employing 'decomposed EKC model into scale effect, technique effect and composition effect'. Moreover, the energy consumption and trade openness effect is an additional control variables.

Moreover, recent discussion over energy and environment has been subject to continued ongoing globalization and smooth spells of trade liberalization (Ahmed, 2014), thus suggests sustainability both in terms of development-wide and energy-wide openness in trade is considered as the most important factor. Although in case of industrialized

countries strong policy guidelines and sufficient literature is available, the ongoing debate requires future formulation of policy recommendation both for making strategies and abatement of environmental degradation. Doing so, this empirical study attempts to investigate the effect of trade openness on ecological footprint (EF) for the panel of high income, upper middle and lower middle income countries for thirty five Asian economies. For last many years, the state of ecosystem in Asia has been declining. Unsustainable exploitation of marine resources and extensive coastal development have resulted in the destruction of coastal habitats such as salt marshes, wetlands, seagrasses, mangroves and corals. Freshwater ecosystem have been converted for the use of agriculture and polluted with urban waste and their natural flow has been disrupted by storage of water for hydropower, domestic use, agriculture. This has led to reduce access to clean water, declining freshwater fish stocks and low agriculture productivity. The gap between the natural resource demand (ecological footprint) and the environment's ability to replenish those resources (biocapacity deficit) in Asian countries is widening. The effect of this rising biocapacity deficit can potentially lead to worsening climate change, overharvesting of renewable resources, widespread habitat loss, and environmental degradation. According to global footprint network (GFN), the national EF of Japan, Indonesia, India and China together contribute more than three quarters of the total EF of the Asian region. However, due to its large population, China is the largest of all the countries of Asia, in terms of national footprint consumption. Moreover, these countries rely on non-renewable energy source to meet their energy needs and are heavily dependent on import with no let expected in the near future. The demand for energy in Asian countries will continue to increase and will surpass in terms of global energy demand with rest of the world (United Nations, 2010). The greatest challenge for all the countries of Asia is to manage their natural capital<sup>1</sup> so that they maintain these services in the interest of long term growth without degrading the ecosystem services that underpin the natural environment and livelihood.

Since international trade plays an important role in country's development and provides a better indication of the growth process over time. There is a need of close examination of the relationship between environmental degradation and its influencing macroeconomic factors to design nuance trade, energy and environmental policy. The importance of trade openness can be viewed as fostering technology transfer and coordination across countries to combat climate change. Moreover, energy consumption can be viewed as increasing fossil-fuel consumption and providing inefficiency in natural resources consumption. Hence trade factor are expected to enhance environmental quality while energy consumption are expected to deteriorate environmental quality<sup>2</sup>. The empirical work aims to analyze the impact of trade openness on the ecological footprint. Though several panel studies have been conducted on the group of countries like Gulf cooperation council (GCC), European Union, Middle East and North Africa (MENA) countries, but given the importance of ecological footprint and its widening biocapacity in the region, we have selected the Asian countries to shed some more light on these economies. The study contributes to the literature in the following ways: (i) To author's knowledge, there is no such article that employs these variables based on the income groups of Asian countries in the same framework as examined in this paper. In the relevant literature the study is gaining interest since much concern for sustainable growth in

<sup>1</sup> Natural capital such as marine, coastal, freshwater, biodiversity and forests ecosystem is important in making green economies. It is the stock of natural resources and assets that provide ecosystem services such as absorption of human waste products like CO<sub>2</sub>, pollination of crops, timber, water and food.

<sup>2</sup> There may be possibility of pollution haven hypothesis. This is because sometimes trade happens to be bad for developing countries, it is when developed nations seek to set up factories abroad, they often look for cheap labor and resources. This comes only at the cost of environmentally unsound practices.

Asia, especially these two economies India and China have experienced high economic growth without any concern relative to environmental degradation issues. Climate change in these region is one of the significant environmental challenges. These Asian countries are featured by substantial differences across their energy consumption and their level of ecological footprint and trade openness, which are further likely to worsen the association between their per capita income and the environmental degradation, threatening their significant economic development (Liu et al., 2017; Le et al., 2020). (ii) In the context of Asian countries, the studies investigated the Environmental Kuznets curve hypothesis by employing CO<sub>2</sub> emissions as a measure of environmental pollution, thus our study employs ecological footprint indicator to measure the emissions level which is more comprehensive measure of environmental pollution. (iii) The examination of the Asian countries is of interest of policy makers and researchers since carbon emissions over the past few decades are highly rising as compared to the rest of the world according to the World Development Indicator where carbon component makes 47 percent or more of the total ecological footprint. Moreover, per capita ecological footprint consumption (1.6 gha) in these countries, according to the global footprint network far exceeds the available bio capacity per capita (0.9 gha), leaving the biocapacity deficit of 0.8 gha per capita. (iv) While examining the environmental Kuznets curve relationship, it appears that grouping on the basis of income is an important factor, therefore to reach out the income level homogenously, we grouped Asian countries into high income, upper middle and lower middle income countries. (v) It is pioneering effort in examining the association between the ecological footprint and trade openness by adding scale, technique, and composition effects in ecological footprint function. (vi) We employed second generation unit root test such as the cross sectionally augmented IPS (CIPS) and cross sectionally augmented Dickey-fuller (CADF) along with test of West-erlund cointegration for checking the long run relationship among the variables which takes the issues of both heterogeneity and cross sectional dependence.

The remaining part is assembled as follows: “Literature Review” section supply assessment of relevant studies. The “Empirical modelling, data and methodology” part delineates the model specification, data collection, and methods applied. The results and discussion are reported in the “Empirical Results and discussion” division, The “Panel Granger causality test” presents pairwise granger causality effect among the variables, and the “conclusion and policy implication” division summarizes article with concluding remark and some relevant policy implications.

## 2. Literature review

The prevailing literature on environment-trade nexus has contributed mixed outcome. This association among trade openness and environmental quality was first attempted by Grossman and Krueger (1991). Later, Lucas et al. (1992) investigated the relationship between trade and pollution intensity and found that with the rise in income along with trade there is reduction of pollution intensity. Grossman and Krueger (1994) examined the impact of trade openness on the quality of environment. Their empirical outcome show that openness in trade reduces environmental degradation and increases specialization in unskilled labour intensive goods in Mexico and its neighbouring countries. Porter and van der Linde (1995) argue that strict environmental regulation encourage innovations and increase efficiency. They further analyze that trade openness improves environmental quality via income growth. Economic growth has negative impact whereas trade openness has statistically insignificant on carbon emissions when Gale and Mendez (1998) examine the relationship between environmental quality, economic growth and trade openness. Dean (2002) investigated the association among trade openness, urbanization, population density, carbon emissions and found that increase in economic growth mitigates environmental pollution whereas increases in trade openness aggravates

carbon emissions (Ozturk, 2010; Jalil and Mahmud, 2009; Ang, 2008; Ghosh, 2010). Levinson and Taylor (2008) found that larger net import will take place because of strict environmental regulations. There are other number of studies which examines the long run association between CO<sub>2</sub> emissions and openness in trade (Shahbaz et al., 2015; Bhattacharyya and Ghoshal, 2010; Lee et al., 2009)

Frankel and Rose (2005), Antweiler et al. (2001), and Liddle (2001) found that for developed and developing countries trade is good for environmental quality. On contrary, Baek et al. (2009), Dinda and Coondoo (2006), and Mani and Wheeler (1998) supported that trade openness may have negative impact on the environment in developed countries and free trade may deteriorate environmental quality in developing countries. Kukla-Gryz (2009) mentioned that in developing countries trade openness positively influence environmental pollution at early stage of economic development. Takeda and Matsuura (2006) examined the relationship between CO<sub>2</sub> emissions, export, import spanning the period 1988–2000 for East Asian countries. Their empirical results reveals that increasing dirty import from Japan, United states (US) do not harm the environmental quality, while increasing dirty export to Japan, domestic economic activity inclined to raise environmental pollution in East Asia. Using Turkish data, Halicioglu (2009) analyzed the granger causal relationship among CO<sub>2</sub> emissions, energy use, growth, and trade. Their findings indicate that energy use, country's growth and openness in trade leads to environmental degradation. But, Iwata et al. (2012) noted that in Organisation for Economic Cooperation and Development (OECD), country's trade affects CO<sub>2</sub> emissions insignificantly. Managi et al. (2009) investigated the relationship between environmental quality, economic growth, and openness in trade and found that trade openness lowers CO<sub>2</sub> emissions in OECD countries while it increase in non-OECD nations. Ahmed et al. (2019) reported that openness in trade lowers environmental quality in 8 developing countries, this is because they did not follow World trade organisation (WTO) regulations. However, to examined the trade-induces pollution in developing nations, recent arguments made by different scholars (Kearsley and Riddel, 2010; Sun et al., 2017; Ansari et al., 2019; Nadeem et al., 2020; Li et al., 2020) on pollution haven hypothesis<sup>3</sup>.

Shao et al. (2019) investigated that pollution haven hypothesis (PHH) does not exist in case of BRICS<sup>4</sup> countries. Nadeem et al. (2020) used autoregressive distributed lag model (ARDL) and employed four different indicators of environmental degradation to explore the existence of PHH in Pakistan over the period from 1971 to 2014. Their empirical findings indicate that foreign direct investment (FDI) inflow and Sulfur dioxide (SO<sub>2</sub>) emissions show negative long run relationship while FDI inflow and Greenhouse gas (GHG), CO<sub>2</sub> and CO<sub>2</sub> from solid fuels show positive long run relationship. Hence they did not find any evidence in support of PHH. For Asian economies, Hanif et al. (2019) examined the short run and long run impact of economic growth, FDI, energy consumption on carbon emissions and concluded that FDI is a significant source of environmental pollution in 15 developing Asian countries. Khan and Ozturk (2020) investigated the causal linkages among CO<sub>2</sub> emissions and FDI in case of Asia. The findings indicate that the panel cointegration confirms the presence of long run association and found bidirectional granger causal between CO<sub>2</sub> emissions and FDI inflow. By employing panel data technique Huynh and Hoang (2019) revealed that FDI inflows affect air pollution in 19 Asian economies. Using Ecological footprint indicator as a proxy for environmental pollution Destek and Okumus (2019) analyzed the linkages between energy use, country's growth, FDI and ecological footprint in newly industrialized countries. Their results showed U-shaped association between FDI and EF.

Moreover, Ozturk et al. (2016) probed the association among real

<sup>3</sup> When developed nations often look for the cheapest options in terms of labour and resource, and plan to set up factories abroad.

<sup>4</sup> Brazil, Russia, India, China, and South Africa.

income, urbanization, trade openness and EF for high and upper middle income nations by using generalized method of moments (GMM) over the period 1988–2008 in 144 countries. Their empirical result reported that the number of examined countries have a negative relationship among them. Uddin et al. (2017) applied the dynamic ordinary least squares (DOLS) model to examine the association between trade openness and ecological footprint for 27 highest emitting countries. The outcome show that real income is detrimental to ecological footprint, but openness in trade have benefits it. Similarly, Mrabet and Alsamara (2017) studies the impact of trade openness, economic growth, energy consumption on two different environmental indicators: ecological footprint (EF) and CO<sub>2</sub> emissions by using ARDL model in the case of Qatar. Their findings reported that trade openness is detrimental to environmental quality when they use the CO<sub>2</sub> emissions whereas it improves the environmental quality when using the ecological footprint. In the case of European Union, Destek et al. (2018) used ecological footprint and reported that trade openness have negative impact on ecological footprint, but Ulucak and Bilgili (2018) noted that trade openness degrade quality of environment in high, middle and low income countries. Recently, Destek and Sinha (2020) incorporated the role of ecological footprint in trade-pollution nexus for 24 OECD countries. Using second generation panel data methodologies they found that economic growth increases ecological footprint while openness in trade reduces it.

In case of Asian countries, researchers have listed down the various arguments regarding the effect of international trade on Ecological footprint and examined its empirical evidences. For example, Liu et al. (2017) analyzed the trade-emissions nexus for 42 Asian countries from 2007 to 2016 and found that trade openness have significant effect on the ecological footprint. Later studies by Ansari et al. (2020c) found the statistically positive impact of trade openness on emissions in case of West Asia and statistically negative impact in Central, East, South, and Southeast Asian countries. Lee (2019) investigated the lagged effect of urbanization, industrialization and export on carbon footprint in case of Southeast Asia. He noted that only at the cost of carbon footprint, urbanization, export and economic growth is achieved. Similarly, Sabir and Gorus (2019) also found that ecological footprint are positively impacted by trade openness during 1975–2017 for the South Asian countries. More recently, Le et al. (2020) examined the relationship between trade openness, energy consumption, and economic growth on environmental degradation in 31 Asian nations over the period of 2004–2014. Their empirical finding reveals that economic growth and energy consumption increases emissions meanwhile, trade openness reduces pollution in the region. In other individual Asian countries like India, Shahbaz et al. (2015) used globalization as a proxy for trade openness and noticed that its effect on environment is negative, similar results were also reported by Nasir and Rehman (2011), and Aroui et al. (2014) for Pakistan and Thailand respectively. Unlike, Tiwari et al. (2013)<sup>5</sup>, Shahbaz et al. (2015) found openness in trade is beneficial for Indian economy.

### 3. Empirical modelling, data and methodology

The empirical study Antweiler et al. (2001) had disintegrated the overall effect of trade on environment into scale, composition and technique effect. The scale effect refers to the scale of economic activity. Higher economic activity leads to higher production due to free trade among the countries which is expected to increase the level of environmental pollution. The government would respond to people's demand by tightening the environmental regulation which leads to cleaner techniques of industrial production improving environmental quality. This is called the technique effect. Finally, the composition effect describes how pollution are impacted by the composition of output which

in turn is decided by the comparative advantage and the degree of trade openness of the country. Our empirical model based on the empirical strategy of Ling et al. (2015) and Jena (2018). They employed per capita gross domestic product (GDP) as a proxy of scale effect, square of per capita GDP as proxy of technique effect and capital labor-ratio as a proxy of composition effect.

Theory explains scale, technique and composition effect as three major channels through which liberalization of trade can affect environment. Per capita GDP and its square term are used to capture the scale and technique effect which is consistent with the environmental Kuznets curve literature. When income level shift from low to high levels, pollution rises and declines which takes an inverted u-shaped relationship, an important inference is to find a threshold point where nonlinear relation between income and environmental degradation exist. The third channel which shows the trade and pollution nexus are composition effect which is captured via capital-labor ratio. The production structure and their stock of factor endowment greatly differ from country to country. The country with capital-intensive industries will produce capital intensive goods and country with labor-intensive industries will produce labor-intensive goods. Therefore, capital-labor ratio that measures the relative capital intensity will produce different levels of production among different countries. Trade openness is measured by trade intensity and is calculated as the ratio of import (IM) plus export (EX) to GDP [(IM + EX)/GDP]. The existence of pollution haven depends on the type of goods exported and imported. Thus, it argues that since developed nations have rigorous environmental regulations, they relocate their pollution intensive output to developing countries where environmental regulations are flexible. The PHH received a considerable attention in developing countries. The other control variable used is energy consumption. It is considered as one of the key factor for increasing environmental pollution. As major portion of energy demand is fulfilled by non-renewable energy source which is responsible for major rise in pollution.

Environmental pollution has a multi-dimensional effect on the ecological system, hence the proxy used for environmental quality has remained mixed. Though CO<sub>2</sub> emissions are extensively analyzed in the literature and remain the centre of international climate change agreements. There are some other important factors like deterioration in the quality of soil, forest, water, etc. are also notable which is facing severe ecological threats (Bartelmus, 2008). These factors are of great importance and an integral part of the ecosystem. Hence ecological footprint indicator based on the concept of carrying capacity of ecosystem is an important issue in the ecological system. Therefore ecological footprint introduced by Wackernagel and Rees (1998) is an accounting based indicator framed to capture the multi-dimensional impact on environmental degradation for which world is facing major threats. Hence recently it has been viewed as a superior measure of environmental quality and can serve as goal variable to target better environmental quality.

The objective of this empirical article is to investigate the influence of international trade on ecological footprint through scale, technique and composition effects. In regard of Asia's export led economic development, we identify consumption of energy to play a significant role in such framework. However, via spill over effect of technological change, openness in trade not only improves energy efficiency but also liberalize increased consumption of energy in an economy. Likewise, as the economy passes transition stage, the impact of trade-growth nexus on environment, changes. In this concern, environmental Kuznets curve (EKC) hypothesis<sup>6</sup> gives standard technique to study the 'inverted u-shaped' association between economic development and environmental pollution. Taking into account the trade openness as independent

<sup>5</sup> trade increases pollution level in India.

<sup>6</sup> Destek et al. (2018), Zhang (2019), Sabir and Gorus (2019), Ahmed et al. (2019), Ansari et al. (2020a) have analysed the validity of EKC hypothesis using ecological footprint indicator.

variable, Cole (2006), and Ling et al. (2015) advises that international trade encourages clean and efficient technology transfer and adequate policy implication towards environment and helps in better formulation of economic policies. Jena and Grote (2008) argued that the trade-emissions nexus via consumption of energy is varied via scale, composition and technique effects. Following Tsurumi and Managi (2010), Zhang (2012), Ling et al. (2015), and Jena (2018), the model is represented by

$$F_t = f(Y_t, Y_t^2, E_t, K_t, T_t) \quad (1)$$

Since we plan to measure the estimated coefficients, transformation of Eq. (1) into log linear form is recommended<sup>7</sup>. This specifies a constant elasticity over all values of the data set and have an interpretation as elasticities. This gives us the % change in regression w.r.t to each regressor, more importantly, it overcomes the difficulty associated with the distributional properties of the variable series and makes the empirical results easy to interpret and comprehend. Thus, Eq. (2) illustrate log linear econometric model as follows:

$$\ln F_t = \beta_1 + \beta_2 \ln Y_t + \beta_3 \ln Y_t^2 + \beta_4 \ln E_t + \beta_5 \ln K_t + \beta_6 \ln T_t + \varepsilon_t \quad (2)$$

Where  $\ln F_t$  is the natural log of per capita ecological footprint measured in global hectares (gha),  $\ln Y_t$  (scale effect) is the natural log of real income,  $\ln Y_t^2$  (technique effect) is the natural log of the square term of real income measured in constant US dollar 2010,  $\ln E_t$  is the natural log of per capita consumption of energy measured in kg of oil equivalent,  $\ln K_t$  (composition effect) is the natural log of capital-labour ratio,  $\ln T_t$  is the natural log of trade openness measured as a percentage of gdp.  $\varepsilon_t$  is the residual term. The yearly data from 1991 to 2016 has been collected from different sources and agencies like data on GDP per capita, Energy consumption and trade openness has been extracted from World Development indicator, data on ecological footprint has been collected from Global Footprint Network, and labour force, gross fixed capita formation data is taken from Penn World Table, version 9.1. Following Al-Mulali et al. (2015), and Ulucak and Bilgili (2018) countries are categorised based on the income level of Asian countries into three sub groups; (1) High income countries- Bahrain, Japan, Israel, Oman, Cyprus, Saudi Arabia, Korea republic, Brunei Darussalam, Singapore, United Arab Emirates (UAE), and Qatar. (2) Upper middle income countries- Jordan, Turkey, Lebanon, Iraq, Iran, Sri Lanka, China, Malaysia, Thailand, Kazakhstan, Armenia, Azerbaijan, and Turkmenistan. (3) Lower middle income countries-Bangladesh, India, Pakistan, Mongolia, Indonesia, Philippines, Vietnam, Kyrgyzstan, Uzbekistan, Myanmar, and Cambodia.

Since, we have employed panel data set, the application of ordinary least square (OLS) is asymptotically biased and its distribution depends upon the nuisance parameter. The nuisance parameter in the course of regression estimation, can result due to presence of endogeneity and serial correlation among the regressors. Therefore, to overcome these issues, fully modified ordinary least square (FMOLS) method is used developed by Pedroni (2000, 2001). This technique uses a non-parametric approach to address the issue of serial correlation and endogeneity Eq. (2), in the present analysis is examined for long run relationship among the variable via Fisher, Pedroni, Kao and Westerlund cointegration test statistics. After finding cointegration among ecological footprint, scale effect, technique effect, energy effect, composition effect, and trade effect, long run results are estimated via panel FMOLS. Further, for robustness of the model dynamic ordinary least square (DOLS) are also tested.

<sup>7</sup> A linear relationship provides us approximate explanation of some economic behaviour among the variables. The other feasible alternative is a log-log model where both explanatory as well as dependent variables are converted into log form. The difference between the linear model and log linear model is that former gives us marginal effect and later one as elasticities.

#### 4. Empirical results and discussion

Table 1 presents descriptive test and correlation matrix analysis of Asian countries. We find different level in per capita consumption of energy: 4.778 kg of oil equivalent is lowest and 10.004 is highest level. Similarly, capitalization ranges from 6.876 to 13.925 and trade openness as a percentage of GDP ranges from -3.863 to 6.080. Ecological footprint per capita consumption and real income ranges from -0.766 to 2.830 and 5.247 to 11.175 respectively. All the variables in the correlation matrix are positively correlated.

Since this empirical work employs panel data technique, it would therefore be imperative to check the data for cross sectional dependence (CSD) tests<sup>8</sup> to avoid any misspecification. Thus, this empirical analysis applies four different cross sectional dependence test statistics and the outcome are presented in Table 2. Referring to probability value from the table, the null hypothesis of independence cross sectional tests is rejected for ecological footprint, economic growth, energy consumption, capitalization and trade openness at 1 or 5% level of significance. Therefore the variables incorporated into the analysis have cross sectional dependence, thus we can proceed to use second generation cross sectionally augmented IPS (CIPS) and cross sectionally augmented Dickey-fuller (CADF) unit root test which take both issues into account.

##### 4.1. Unit root analysis

This empirical study prefer CIPS and CADF unit root statistics developed by Pesaran (2007) to ones such that augmented Dickey-Fuller (ADF), and Phillips-Perron (PP) unit root of first generation. Given the drawbacks of assuming homogeneity and cross-sectional independence, the first generation test is likely to produce inefficient results. As these unit root test fails to take the issues of cross sectional dependence into account, hence we have used the CIPS and CADF statistics which gives reliable outcome in the presence of both heterogeneity and CSD. The unit root results of second generation for Asian panel, high income, upper and lower middle income countries are shown in Table 3. Both tests indicate that ecological footprint ( $\ln F_t$ ) economic growth ( $\ln Y_t$ ), square of economic growth ( $\ln Y_t^2$ ), energy consumption ( $\ln E_t$ ), trade openness ( $\ln T_t$ ), and composition effect ( $\ln K_t$ ) are not stationary (unit root) at their level form but at their first difference they become stationary (no unit root), therefore the considered variables are integrated of order one I(1). For economically and statistically meaningful long run coefficient estimates of the regressor, the panel data either should be stationary or cointegrated at their levels. Because  $F$ ,  $Y$ ,  $Y^2$ ,  $E$ ,  $K$ , and  $T$  contains unit root at their level form, this empirical work uses four prominent cointegration analysis: such as

**Table 1**  
Descriptive statistics and correlation matrix.

| Variables          | lnF    | lnY    | lnE    | lnK    | lnT    |
|--------------------|--------|--------|--------|--------|--------|
| Mean               | 1.014  | 8.499  | 7.370  | 11.303 | 4.199  |
| Median             | 0.982  | 8.373  | 7.328  | 11.516 | 4.363  |
| Maximum            | 2.830  | 11.175 | 10.004 | 13.925 | 6.080  |
| Minimum            | -0.766 | 5.247  | 4.778  | 6.876  | -3.863 |
| Std. Dev.          | 0.803  | 1.455  | 1.139  | 1.405  | 1.041  |
| Correlation matrix |        |        |        |        |        |
| lnF                | 1.000  |        |        |        |        |
| lnY                | 0.852  | 1.000  |        |        |        |
| lnE                | 0.915  | 0.880  | 1.000  |        |        |
| lnK                | 0.753  | 0.854  | 0.779  | 1.000  |        |
| lnT                | 0.338  | 0.334  | 0.329  | 0.402  | 1.000  |

<sup>8</sup> Lagrange multiplier statistics proposed by Breusch, and Pagan (1980), and CSD test developed by Pesaran (2004).



**Table 2**  
Results from cross sectional independence test.

|                     | Breusch Pagan<br>LM | Pesaran scaled<br>LM | Bias-corrected scaled<br>LM | Pesaran<br>CD |
|---------------------|---------------------|----------------------|-----------------------------|---------------|
| Asian panel         |                     |                      |                             |               |
| lnF                 | 5042.242*           | 127.904*             | 127.204*                    | 24.635*       |
| lnY                 | 9929.634*           | 269.582*             | 268.882*                    | 74.321*       |
| lnY <sup>2</sup>    | 9966.013*           | 270.637*             | 269.937*                    | 74.347*       |
| lnE                 | 5113.099*           | 129.958*             | 129.258*                    | 18.358*       |
| lnK                 | 7544.016*           | 200.427*             | 199.727*                    | 38.753*       |
| lnT                 | 3482.660*           | 82.694*              | 81.994*                     | 16.027*       |
| High income         |                     |                      |                             |               |
| lnF                 | 379.644*            | 29.904*              | 29.684*                     | 4.552*        |
| lnY                 | 565.902*            | 47.663*              | 47.443*                     | 6.742*        |
| lnY <sup>2</sup>    | 565.431*            | 47.618*              | 47.398*                     | 6.670*        |
| lnE                 | 333.373*            | 25.493*              | 25.273*                     | 2.769*        |
| lnK                 | 698.036*            | 60.262*              | 60.042*                     | 5.633*        |
| lnT                 | 344.600*            | 26.563*              | 26.343*                     | 10.063*       |
| Upper middle income |                     |                      |                             |               |
| lnF                 | 668.508*            | 46.237*              | 45.977*                     | 14.527*       |
| lnY                 | 1516.809*           | 114.156*             | 113.896*                    | 38.712*       |
| lnY <sup>2</sup>    | 1524.850*           | 114.799*             | 114.539*                    | 38.824*       |
| lnE                 | 683.295*            | 47.421*              | 47.161*                     | 12.446*       |
| lnK                 | 903.174*            | 65.026*              | 64.766*                     | 14.302*       |
| lnT                 | 331.634*            | 19.266*              | 19.006*                     | 1.992**       |
| Lower middle income |                     |                      |                             |               |
| lnF                 | 572.013*            | 48.246*              | 48.026*                     | 11.037*       |
| lnY                 | 1211.113*           | 109.182*             | 108.962*                    | 34.638*       |
| lnY <sup>2</sup>    | 1222.036*           | 110.223*             | 110.003*                    | 34.806*       |
| lnE                 | 601.130*            | 51.022*              | 50.802*                     | 7.045*        |
| lnK                 | 710.572*            | 61.457*              | 61.237*                     | 15.811*       |
| lnT                 | 347.688*            | 26.857*              | 26.637*                     | 5.690*        |

\* &amp; \*\* denote statistical significance at 1 and 5 percent level respectively.

**Table 3**  
Results from panel unit root tests.

| Asian panel         | CADF   |          | CIPS   |          |
|---------------------|--------|----------|--------|----------|
|                     | Level  | $\Delta$ | Level  | $\Delta$ |
| lnF                 | -2.449 | -2.973*  | -2.593 | -4.769*  |
| lnY                 | -2.205 | -2.822*  | -2.128 | -3.721*  |
| lnY <sup>2</sup>    | -2.176 | -2.690*  | -2.128 | -3.817*  |
| lnE                 | -2.102 | -3.094*  | -2.436 | -4.780*  |
| lnK                 | -1.712 | -2.291*  | -1.331 | -2.951*  |
| lnT                 | -2.030 | -3.650*  | -2.951 | -4.294*  |
| High income         |        |          |        |          |
| lnF                 | -1.506 | -3.130*  | -1.663 | -5.300*  |
| lnY                 | -1.343 | -2.351*  | -1.295 | -3.724*  |
| lnY <sup>2</sup>    | -1.657 | -3.129*  | -1.288 | -3.732*  |
| lnE                 | -1.166 | -3.109*  | -1.366 | -4.785*  |
| lnK                 | -1.433 | -2.228*  | -1.005 | -2.421*  |
| lnT                 | -2.200 | -3.317*  | -2.217 | -4.333*  |
| Upper middle income |        |          |        |          |
| lnF                 | -2.258 | -2.734*  | -2.770 | -4.746*  |
| lnY                 | -2.222 | -2.802*  | -2.288 | -3.951*  |
| lnY <sup>2</sup>    | -2.056 | -2.769*  | -2.182 | -3.904*  |
| lnE                 | -2.241 | -2.776*  | -2.816 | -4.617*  |
| lnK                 | -1.118 | -2.450*  | -0.859 | -3.221*  |
| lnT                 | -1.997 | -2.805*  | -1.826 | -4.039*  |
| Lower middle income |        |          |        |          |
| lnF                 | -1.895 | -2.888*  | -1.919 | -4.746*  |
| lnY                 | -1.898 | -2.863*  | -2.127 | -3.382*  |
| lnY <sup>2</sup>    | -2.010 | -2.798*  | -2.134 | -3.323*  |
| lnE                 | -1.201 | -2.898*  | -1.387 | -4.247*  |
| lnK                 | -1.217 | -2.250*  | -1.224 | -2.520*  |
| lnT                 | -1.384 | -3.147*  | -1.819 | -4.538*  |

 $\Delta$  denotes the first differences.

\* denote the statistical significance at 1 percent level.

Fisher-type Johansen cointegration analysis, Kao cointegration test, the Pedroni and Westerlund cointegration test of second generation to analyze the long run association between the variables of Eq. (2).

#### 4.2. Cointegration analysis

This empirical work searches for possible long run association among the examined variables firstly by employing the Pedroni cointegration test due to Pedroni (1999)<sup>9</sup> in Asian panel, high income, upper and lower middle income countries. The Pedroni cointegration statistics consist of seven tests out of which four test are within dimension approach and three are between dimension approaches as shown in panel A Table 4. The findings from pedroni long run relationship show four out of seven tests are statistically significant at 1, 5 and 10 percent level of significance, which confirms the majority of the test statistics in Asian panel, high income, upper, and lower middle income countries are cointegrated and exhibits long run relationship among analysed variables.

Secondly, the Panel Kao cointegration tests proposed by Kao (1999) includes cross homogeneous coefficients and follows the similar procedure as the pedroni test on the first stage regressors. Referring to the associated p values in Table 5, the null hypothesis of no cointegration is highly rejected at 1 percent significance level which indicate the analyzed variables in all the group panels are cointegrated and have long run relationship. The third test is applied is Johansen Fisher cointegration test developed by Maddala and Wu (1999)<sup>10</sup>. The empirical results are presented in lower panel of Table 5, which shows that there is significant long run relationship among ecological footprint, economic growth, energy consumption, capitalization, and trade openness in all the sub panels. All these test have been majorly employed in several studies including the growth-emissions-energy literature, have limitations of considering independent cross sections that considered first generation cointegration tests. Therefore, this article also uses second generation Westerlund cointegration test developed by Westerlund

**Table 4**  
Results from Pedroni and Westerlund cointegration tests.

| Panel: A Pedroni<br>cointegration test    | Asian<br>panel | High<br>income | Upper<br>middle<br>income | Lower middle<br>income |
|-------------------------------------------|----------------|----------------|---------------------------|------------------------|
| Common AR coefs<br>(within<br>dimension)  | Statistics     | Statistics     | Statistics                | Statistics             |
| Panel v-statistics                        | -0.454         | -0.746         | 0.648                     | -1.305                 |
| Panel rho-statistics                      | 1.442          | 1.126          | 0.065                     | 1.725                  |
| Panel PP-statistics                       | -5.168*        | -1.907**       | -6.324*                   | -1.544***              |
| Panel ADF-statistics                      | -6.434*        | -2.474*        | -6.694*                   | -1.880**               |
| Individual AR coefs (between dimension)   |                |                |                           |                        |
| Group rho-statistics                      | 3.417          | 1.585          | 1.841                     | 3.271                  |
| Group PP-statistics                       | -6.055*        | -3.614*        | -5.457*                   | -4.296*                |
| Group ADF-statistics                      | -8.177*        | -4.280*        | -6.289*                   | -3.226*                |
| Panel: B Westerlund<br>cointegration test | Statistics     | Statistics     | Statistics                | Statistics             |
| Gt                                        | -4.321*        | -3.754*        | 3.467*                    | 2.451**                |
| Ga                                        | -8.526*        | -7.784         | -6.542                    | -6.103*                |
| Pt                                        | -12.704*       | -11.798        | -13.511*                  | -12.012*               |
| Pa                                        | -6.619         | -6.174*        | -7.937*                   | -6.931                 |

\*, \*\* & \*\*\* denote the statistical significance at 1, 5 and 10 percent level respectively. Gt, Ga and Pt Pa indicate cointegration for individual and panel group respectively.

<sup>9</sup> This tests is applicable for heterogeneous panels.<sup>10</sup> This tests is based on the aggregated p values showing trace statistics and maximum eigenvalues individually and depends heavily on the number of lags of the vector autoregressive system.

**Table 5**  
Results from Kao and Johansen Fisher cointegration tests.

|                                    | Asian panel  |                 | High income  |                 | Upper middle income |                 | Lower middle income |                 |
|------------------------------------|--------------|-----------------|--------------|-----------------|---------------------|-----------------|---------------------|-----------------|
| Augmented Dickey-Fuller (ADF) test | t-statistics |                 | t-statistics |                 | t-statistics        |                 | t-statistics        |                 |
|                                    | −7.636*      |                 | −3.680*      |                 | −8.189*             |                 | −3.910*             |                 |
| Fisher cointegration rank test     |              |                 |              |                 |                     |                 |                     |                 |
| Hypothesized no. of CE(s)          | Trace value  | Max Eigen value | Trace value  | Max Eigen value | Trace value         | Max Eigen value | Trace value         | Max Eigen value |
| $r = 0$                            | 1396.0*      | 726.4*          | 412.3*       | 216.5*          | 550.0*              | 297.8*          | 434.1*              | 212.0*          |
| $r \leq 1$                         | 826.3*       | 408.3*          | 235.7*       | 125.0*          | 319.2*              | 148.8*          | 271.4*              | 134.5*          |
| $r \leq 2$                         | 499.4*       | 272.9*          | 133.5*       | 78.91*          | 200.5*              | 104.8*          | 165.4*              | 89.19*          |
| $r \leq 3$                         | 287.2*       | 180.7*          | 73.36*       | 47.48*          | 117.2*              | 71.45*          | 96.65*              | 61.80*          |
| $r \leq 4$                         | 177.5*       | 153.5*          | 46.86*       | 34.5**          | 71.65*              | 68.41*          | 58.99*              | 50.57*          |
| $r \leq 5$                         | 126.3*       | 126.3*          | 50.81*       | 50.8*           | 37.51***            | 37.51***        | 37.9**              | 37.9**          |

\*, \*\* & \*\*\* denote the statistical significance at 1, 5 and 10 percent level respectively.

(2007) which considered the issue of cross sectional dependence into account and gives accurate and efficient results. The results of said cointegration are reported in panel B Table 4, which shows out of four test statistics (Gt, Ga, Pt, and Pa), the findings in three cointegration support the existence of long run relationship in all the Asian panels.

#### 4.3. Long-run estimates

After we confirm that economic growth (scale effect), square of economic growth (technique effect), energy consumption, capitalization (composition effect), and trade openness has a long run relationship in Asian panel, high income, upper and lower middle income countries, then comes an important inference for researchers to analyse the long run coefficients of the regressors. The literature uses ordinary least square (OLS) which is very popular and commonly used ones; however, the DOLS and FMOLS techniques have been recently preferred over OLS method (Lee et al., 2009). These estimators have advantage in eliminating autocorrelation problem in the residual terms and endogeneity issues in the explanatory variables (Bhattacharya et al., 2016). In addition, by using parametric approach DOLS methods gets rid of the problem of its lags and leads of the regressors while the FMOLS technique eliminates the problem of serial correlation and endogeneity. It appears that income level is important in testing the environment Kuznets curve. To be able to reach homogeneous income level estimations, we classified countries into four sub panels; Asian panel, high income, upper and lower middle income countries by employing FMOLS and the DOLS approach. The empirical findings from FMOLS and DOLS estimators are provided in Tables 6 and 7 respectively. The coefficient described are statistically significant at 1, 5 and 10 percent level. Because the panel time series variables are in natural log, the long run  $F$  with respect to  $Y$ ,  $Y^2$ , energy consumption, composition effect, and trade openness are econometrically equal to the elasticities of ecological footprint. Although, the coefficient magnitudes in all panels differ across the considered estimators, the results of FMOLS is same as the DOLS<sup>11</sup>. The empirical finding reveals that while achieving economies of scale, the coefficient estimates of scale effect is positive on ecological footprint. However, when there is a changes in technology because of the transition in economy of scale this effect turns from positive to negative, where upsurge in real income reduces environmental pollution, though their magnitudes of estimated coefficients changes across the four sub panels. More precisely, the marginal effect of scale on  $F$  is computed by  $\beta_1 + 2\beta_2^*Y$  show that the outcome of scale effect on ecological footprint is clearly positive in the early stage of economic development, but it decreases and eventually becomes negative as they shift to technology-

based economic growth. In other words, increases in the economies of scale leads to environmental improvements as the Asian countries, high income, upper, and lower middle income countries pass the threshold income level (technology effect). This shows that the linear and non-linear association between scale and technique effect in terms of economic growth and ecological footprint is 'inverted U-shaped', this validate the presence of environmental Kuznets curve (EKC) hypothesis in all four panels. Our empirical findings suggest that rise in economic activity does not deteriorate environmental quality of Asian countries this is because income encourages the adoption of newer technology which leads to cleaner production. This empirical evidence of EKC is in line with Aşıcı and Acar (2016), Mrabet and Alsamara (2017), Charfeddine and Mrabet (2017), Ulucak and Bilgili (2018), Hassan et al. (2019), Ansari et al. (2020b), Fakher (2019). On the contrary, Begum et al. (2015) analyzed the dynamic impact of economic growth, energy consumption on CO<sub>2</sub> emissions using ARDL approach spanning the period 1980–2009. Their empirical finding showed per capita CO<sub>2</sub> emissions decreased with increasing economic growth and increased sharply with a further increase of per capita GDP which did not support the EKC hypothesis in Malaysia. Similarly, Destek et al. (2018) and Ansari et al. (2020c) also examines the EKC for European and top CO<sub>2</sub> emitter countries respectively. Their empirical finding showed U-shaped relationship between the real income and ecological footprint. Furthermore, this study are similar to the study of Tsurumi and Managi (2010), Zhang (2012), Ling et al. (2015), and Jena (2018) who also examined the impact of scale, technique and composition effect on environmental degradation and found that scale effect ultimately degrades the quality of environment while technique effect improves the environmental quality in the long run.

Regarding the impact of energy consumption on ecological footprint, increases in consumption of energy stimulates the environmental pollution. A 1 percent increase in  $E$  boosts  $F$  by 0.05%–0.66%. This empirical outcome is same as reported by Ling et al. (2015), Dogan and Seker (2016), Destek et al. (2018), Ahmed et al. (2019). The energy consumption is required to achieve the level of economic growth, as these nations are characterised by high economic growth. The existing renewable energy solutions are not yet mature enough to fulfil the present level of demand of energy, as these nations mostly rely on the fossil fuel energy solution (Sinha, 2017). Because usage of energy is a necessary and an important source in the production process, it is quite impossible for countries to stop using energy. This continued consumption of fossil fuel has created a disturbance in the environment by resulting in rise in the ecological footprint. So for ensuring clean and sustainable development, these income group countries are advised to increase the share of consumption of renewable energy as well as to increase the energy efficiency level. Referring to Apergis and Ozturk (2015) who suggested that increases in the consumption of bio-diesel fuels stimulate environmental problem whereas increases in

<sup>11</sup> In case of DOLS some variables are insignificant but signs are same as in FMOLS.

**Table 6**  
Results from FMOLS.

| Variables               | Asian panel |       | High income |       | Upper middle income |       | Lower middle income |       |
|-------------------------|-------------|-------|-------------|-------|---------------------|-------|---------------------|-------|
|                         | Coefficient | Prob. | Coefficient | Prob. | Coefficient         | Prob. | Coefficient         | Prob. |
| lnY                     | 0.563*      | 0.000 | 4.996*      | 0.000 | 1.482*              | 0.000 | 1.520*              | 0.000 |
| lnY <sup>2</sup>        | −0.028*     | 0.000 | −0.120**    | 0.045 | −0.086*             | 0.000 | −0.047*             | 0.000 |
| lnE                     | 0.654*      | 0.000 | 0.375*      | 0.000 | 0.664*              | 0.000 | 0.439*              | 0.000 |
| lnK                     | 0.042*      | 0.000 | −0.134*     | 0.001 | −0.034***           | 0.082 | −0.114*             | 0.000 |
| lnT                     | −0.010**    | 0.042 | −0.113***   | 0.072 | −0.015*             | 0.000 | 0.060**             | 0.022 |
| R <sup>2</sup>          | 0.982       |       | 0.877       |       | 0.957               |       | 0.986               |       |
| Adjusted R <sup>2</sup> | 0.981       |       | 0.857       |       | 0.955               |       | 0.985               |       |
| Obs.                    | 875         |       | 275         |       | 325                 |       | 275                 |       |

Ecological footprint (F) is the dependent variable

\*, \*\* & \*\*\* denote the statistical significance at 1, 5 and 10 percent level respectively.

**Table 7**  
Results from DOLS.

| Variables               | Asian panel |       | High income |       | Upper middle income |       | Lower middle income |       |
|-------------------------|-------------|-------|-------------|-------|---------------------|-------|---------------------|-------|
|                         | Coefficient | Prob. | Coefficient | Prob. | Coefficient         | Prob. | Coefficient         | Prob. |
| lnY                     | 1.136*      | 0.000 | 5.749***    | 0.096 | 2.162*              | 0.007 | 0.730***            | 0.055 |
| lnY <sup>2</sup>        | −0.054*     | 0.004 | −0.272***   | 0.095 | −0.121**            | 0.011 | −0.010              | 0.687 |
| lnE                     | 0.430*      | 0.000 | 0.226***    | 0.053 | 0.629*              | 0.000 | 0.176*              | 0.000 |
| lnK                     | 0.183*      | 0.000 | −0.492*     | 0.000 | −0.038              | 0.596 | −0.148*             | 0.000 |
| lnT                     | −0.032*     | 0.000 | −0.085      | 0.205 | −0.032**            | 0.019 | 0.005***            | 0.053 |
| R <sup>2</sup>          | 0.998       |       | 0.983       |       | 0.995               |       | 0.999               |       |
| Adjusted R <sup>2</sup> | 0.993       |       | 0.929       |       | 0.985               |       | 0.996               |       |
| Obs.                    | 805         |       | 253         |       | 299                 |       | 253                 |       |

Ecological footprint (F) is the dependent variable.

\*, \*\* & \*\*\* denote the statistical significance at 1, 5 and 10 percent level respectively.

consumption of renewable energy like wind and solar energy projects lessen the environmental pollution in Asian countries. [Jebli et al. \(2016\)](#) explored that renewable energy consumption decreases the ecological footprint whereas use of non-renewable energy increases them. This indicate that use of renewable energy is an environmentally sustainably source on which the policy adviser should focused more on for the sake of environmental quality. Therefore, the Asian countries should focused more on the development of techniques for increased consumption of renewable energy, energy efficiency and green investments through environmental technologies.

The elasticity of ecological footprint with respect to composition effect is negative and statistically significant meaning that capital-labour ratio require lower level of ecological footprint except for Asian panel. The results show that 1 percent increase in composition effect (capital-labor ratio) lead to decrease in ecological footprint ranges from −0.03 to −0.49 percent. This negative relationship between composition effect and environmental degradation is in line with those of [Tsurumi and Managi \(2010\)](#), and [Ling et al. \(2015\)](#), who also report that increase in composition effect, will upsurge ecological footprint in high income countries and China respectively, but opposite to those of [Cole \(2006\)](#), [Zhang \(2012\)](#), [Jena \(2018\)](#), who analyzed the impact of scale, technique, and composition effect on environmental degradation and found positive relationship between composition effect and environmental pollution. This findings further reveals that using more of labour intensive technique means of production (i.e change in the composition of production line), reduces carbon intensity in the presence of technique effect. Furthermore, [Managi et al. \(2009\)](#) have argued that the previous empirical studies treated per capita income and trade openness variables as exogenous. Income and production level of a country are also affected by the openness in trade this is because in reality, the degree of trade openness can be influence by the economic growth of that country which have not been taken into account by

previous literatures. Due to these specification errors, they<sup>12</sup> believe that the trade induced technique and scale effects cannot be compared with the trade induced composition effect to reach at an overall trade openness effect. In this argument there is a strong reasoning, as per capita income increases, there is rise in technique effect, which also affects the composition of output through environmental regulation-induced comparative advantage. Hence, composition effect is not fully independent of the income effect.

Given these empirical findings, we argue that openness in trade has a negative and significant effect on ecological footprint in all the Asian panels except in the case of lower middle income countries. The coefficient elasticities of ecological footprint with respect to trade openness ranges between (−0.01) and (−0.11). This shows that rise in trade openness mitigate ecological footprint in Asian panel, high income and upper middle income countries. It suggests that trade liberalization in case of Asian and other income group countries is a long run phenomenon. Over the last several years, particularly developed nations have made a great achievement in developing new technologies and the examined group countries seem to take advantage of capital formation, technology and institutional spill over via trade development. Moreover, these countries are likely to produce environment friendly goods and export non-energy intensive products. It seems that the dirty and environmentally-unfriendly goods operated in Asian panel, high, and upper middle income countries relocate their dirty factories to under-developed or less developed countries relatively with less stringent environmental regulations and enforcements, this phenomena is known as pollution-haven hypothesis<sup>13</sup>. Therefore, to enhance environmental quality, long term national policies will increase trade volume in these countries. This negative association between *T* and *F* is consistent with the findings of [Mrabet and Alsamara \(2017\)](#), [Destek et al. \(2018\)](#), [Destek](#)

<sup>12</sup> [Tsurumi and Managi \(2010\)](#), [Managi et al. \(2009\)](#).

<sup>13</sup> When large industrialized countries seek to set up offices or factories abroad, they often look for the cheapest options in terms of resource and labour.

and Sinha (2020) for Qatar, European, and 24 OECD countries. However, significant and positive association was found between  $T$  and  $F$  in the case of lower middle income countries. This findings indicate that the pollution industries are more likely to move from developed to lower middle income Asian countries because the environmental regulations in these income countries are weak and less stringent, hence support pollution haven hypothesis. Similar results were reported by Al-Mulali et al. (2015), Figge et al. (2017), Uddin et al. (2017), and Sabir and Gorus (2019). The reported results also reveal goodness of fit of the specification ( $R^2$ ) ranges from 0.87 to 0.99 which implies that the changes in the dependent variables are well enough explained by the independent variables.

The empirical findings are reliable, robust and strong since we used various cross sectional dependence test, unit root analysis, cointegration statistics, and long run approaches. Although we employed longest available data for the sample countries on the analysed countries, once the longer data become available further studies can potentially obtain more robust results. Moreover, the study employed second generation tests where the outcome of one is confirmed by the other test statistics in the same group.

### 5. Panel granger causality test

In the panel data, granger causality is computed by running bivariate regressions which takes the form

$$X_{it} = \alpha_{0i} + \alpha_{1i}X_{it-1} + \dots + \alpha_{ki}X_{it-k} + \beta_{1i}Y_{it-1} + \dots + \beta_{ki}Y_{it-k} + \varepsilon_{it} \quad (3)$$

$$Y_{it} = \alpha_{0i} + \alpha_{1i}Y_{it-1} + \dots + \alpha_{ki}Y_{it-k} + \beta_{1i}X_{it-1} + \dots + \beta_{ki}X_{it-k} + \varepsilon_{it} \quad (4)$$

Where,  $i$  indicates the cross sectional dimension, and  $t$  indicates the time period dimension. The panel causality test of different forms differ on the assumption made about the homogeneity of the coefficients across cross sections.

For analysing the causal relationship among the variables, we have conducted the pair-wise Granger causality test. The results presented in table 8 show that scale effect granger causes ecological footprint in the long run. This unidirectional of causality running between  $Y$  and  $F$  confirms the existence of EKC hypothesis (Narayan and Narayan, 2010) in all the Asian income group countries including Asian panel. The

results further suggest that there is causality running from Energy consumption to ecological footprint in Asian panel, high income and lower middle income, however, in the case of upper middle income group there is bidirectional causality exist running from  $E$  to  $F$ , this indicate that consumption of energy are the major cause for environmental degradation in the panel countries. These empirical outcomes are consistent with Ling et al. (2015) and Dogan and Seker (2016). Moreover the feedback exist between composition effect and ecological footprint in case of Asian panel countries where trade openness causes ecological footprint only in upper middle income countries<sup>14</sup>.

### 6. Conclusion and policy implications

This article attempts to investigate a question whether international trade obstruct environmental quality or not in case of Asian income group countries; Asian panel, high income, upper, and lower middle income countries spanning the period of 1991–2016. Since majority of researchers have used CO<sub>2</sub> emissions as an indicator of environmental quality, we have employed Ecological footprint function by incorporating energy use effect, scale effect, technique effect, trade effect, and composition effect. For this purpose, the CIPS and CADF unit root test is applied to test the stationary properties of the variables and four different approach to panel cointegration tests is used to examine the presence of long run relationship among  $F$ , scale effect, energy use effect, technique effect, trade effect, and composition effect. The findings revealed the confirmation of cointegration among the variables. The scale effect significantly and positively increases  $F$  while technique effect has negative impact on  $F$  which lowers environmental degradation in all Asian income group countries. Use of energy (energy effect) increases  $F$ , but composition effect lowers  $F$  in all income group. Trade effect reduces  $F$  in high income, and upper middle income while it increases in lower middle income countries. In addition, the granger causality reveals scale effect, composition effect cause ecological footprint and hence  $F$ . Moreover, energy consumption granger causes to  $F$ .

From the policy perspective, the results of this article indicate that under self-correcting mechanism income works, where, due to scale effect there is environmental degradation as it get improved later due to technique effect. This implies that present environmental policies adequately lowers environmental outcome of development process in all the Asian income countries. However, the granger causality running from composition effect to energy use aware toward structural gaps in policy implications in case of Asian countries. The substitution of non-renewable energy sources with non-conventional sources/renewable energy necessarily may not lower ecological footprint provided technique effect sufficiently assist the composition effect. In order to maintain efficiency level, it is important to adopt new and updated technology and significantly shifting from non-renewable to non-conventional source of energy is equally important. Protecting the country from outdated dirty products which comes at the cost of environmentally unsound practices is also an important measures to be taken care of.

In addition, findings also show that liberalization in trade policy lowers environmental degradation and supports economic growth in high income, and upper middle income countries of Asia. This further implies that more openness in trade cause comparative advantage among the trading partner countries which helps in combating greenhouse gas emissions in these income group economies. On the other hand, trade increases environmental pollution in lower middle income countries. These empirical findings enable government official/policy makers to redirect the trade-induced investment inflow and technical change toward improved and better policy framework that can meet sustainable development goals followed by growth oriented policies. Reforms in the energy division section are important in order to

**Table 8**  
Results from Pairwise Granger causality tests.

| Null Hypothesis:<br>No causality | Asian<br>panel<br>F-<br>Statistics | High<br>income<br>F-<br>Statistics | Upper middle<br>income<br>F-Statistics | Lower middle<br>income<br>F-Statistics |
|----------------------------------|------------------------------------|------------------------------------|----------------------------------------|----------------------------------------|
| lnY $\rightarrow$ lnF            | 10.639*                            | 0.106*                             | 6.842*                                 | 5.338*                                 |
| lnF $\rightarrow$ lnY            | 0.994                              | 0.248                              | 0.070                                  | 1.388                                  |
| lnE $\rightarrow$ lnF            | 8.475*                             | 7.496*                             | 12.323***                              | 6.535*                                 |
| lnF $\rightarrow$ lnE            | 0.925                              | 0.892                              | 2.643***                               | 1.322                                  |
| lnK $\rightarrow$ lnF            | 6.770*                             | 0.665                              | 1.312                                  | 0.095                                  |
| lnF $\rightarrow$ lnK            | 7.364*                             | 2.338***                           | 5.809*                                 | 0.687                                  |
| lnT $\rightarrow$ lnF            | 0.635                              | 0.516                              | 6.541*                                 | 0.168                                  |
| lnF $\rightarrow$ lnT            | 4.337**                            | 2.730***                           | 1.850                                  | 0.213                                  |
| lnE $\rightarrow$ lnY            | 6.454**                            | 0.868                              | 0.488                                  | 2.778***                               |
| lnY $\rightarrow$ lnE            | 17.650                             | 5.451*                             | 9.209*                                 | 4.541**                                |
| lnK $\rightarrow$ lnY            | 1.491                              | 6.215*                             | 1.337                                  | 1.444                                  |
| lnY $\rightarrow$ lnK            | 43.253                             | 0.342                              | 9.075*                                 | 8.571*                                 |
| lnT $\rightarrow$ lnY            | 8.983*                             | 1.564                              | 7.161*                                 | 1.467                                  |
| lnY $\rightarrow$ lnT            | 4.593**                            | 0.775                              | 0.772                                  | 0.726                                  |
| lnK $\rightarrow$ lnE            | 16.377                             | 5.371*                             | 3.126**                                | 2.840***                               |
| lnE $\rightarrow$ lnK            | 2.351                              | 0.288                              | 6.692*                                 | 0.162                                  |
| lnT $\rightarrow$ lnE            | 0.429                              | 0.811                              | 11.007                                 | 0.973                                  |
| lnE $\rightarrow$ lnT            | 4.039**                            | 0.224                              | 2.668***                               | 0.068                                  |
| lnT $\rightarrow$ lnK            | 3.564***                           | 0.003                              | 0.832                                  | 4.898*                                 |
| lnK $\rightarrow$ lnT            | 6.775*                             | 1.395                              | 0.123                                  | 5.232*                                 |

\*, \*\* & \*\*\* denote the statistical significance at 1, 5 and 10 percent level respectively.

Lags are auto-selected.

<sup>14</sup> This finding is similar to Lau et al. (2014).



overcome the problem associated with negative effect of environment on economic growth in Asian countries. This article does not only provide adequate policy implications that encourage sustainable economic development in high income, upper middle and lower middle income countries of Asia, but also fill the existing gap on the pollution-growth nexus literature.

Moreover, our empirical work also provide two key characteristic points in the existing literature on environmental Kuznets curve framework; first, it declares presence of EKC hypothesis in all the income group of Asia such as Asian panel, high income, upper middle income, and lower middle income countries, and secondly, it concludes with the sign of granger cause between the analyzed variables. We further decompose EKC model and empirically test the environmental consequences of scale, composition, and technique effect. The reported findings are reliable, robust and strong since we use different econometric techniques and results hold appropriate policy implications for Asian sub panels and helps strategy planner in numerous ways.

This empirical paper has some limitations. This paper focuses the Asian countries only, so the results cannot be generalized. The empirical study focuses on the scale, technique and composition effect, and the comparative advantage effect are ignored. Because of the non-availability of the data, the sample size is limited to the period 1991–2016. Moreover, the collective impact of aggregate energy consumption is examined, and the individual role of renewable and non-renewable energy consumption is not taken into account. These limitations supervise researchers to investigate further studies by taking Asian sub regions geographically or Association of Southeast Asian countries (ASEAN) countries. By employing disaggregate role of renewable and non-renewable energy use, the same study can also be conducted. The factors like urbanization, export, import, financial development, foreign direct investment also cause the ecological footprint, so these variables should also be examined in future research.

## 7. Authors' contributions

All two authors have contributed equally. MAA made the analysis part while NAK compiled introduction, literature review, and the overall formatting of the paper. All authors have read and approved the manuscript.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgements

Not Applicable.

## Ethics approval and consent to participate

Not applicable.

## Consent for publication

Not applicable.

## Availability of data and materials

Data will be available upon request.

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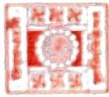
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