The Role of Governance and Foreign Direct Investment in Shaping Environmental Kuznets Curve: Evidence from Developed and Developing Countries

By

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The Role of Governance and Foreign Direct Investment in Shaping Environmental Kuznets Curve: Evidence from Developed and Developing Countries.

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By

Iqbal Hussain

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Dr. Eatzaz Ahmad

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CERTIFICATE OF APPROVAL

This is to certify that research work presented in this thesis titled **"The Role of Governance and Foreign Direct Investment in Shaping Environmental Kuznets Curve: Evidence from Developed and Developing Countries"** was conducted by **Mr. Iqbal Hussain** under the supervision of **Dr. Eatzaz Ahmad, Professor,** Department of Economics, Iqra University, Islamabad.

No part of this thesis has been submitted anywhere else from any other degree. This thesis is submitted to the School of Economics, Quaid-e-Azam University, in partial fulfillment of the requirements for the Degree of Doctor of Philosophy in the field of Economics and is accepted in its present form.

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بسم الله الرحمن الرحيم

Dedication

This thesis is dedicated to my beloved late parents, **DADA & Baabo,** whose tireless sacrifices and unyielding dedication to our future made our education possible. My father’s hard work as a labourer and my mother’s strength and resilience, despite endless struggles, were all for us. Their love, selflessness, and belief in the power of learning remain my deepest inspiration. Though they are no longer with us, their memory continues to guide and uplift me. Gone but never forgotten.

Iqbal Hussain

DECLARATION

I Iqbal Hussain, hereby declare that my PhD thesis titled '**The Role of Governance and Foreign Direct Investment in Shaping The Environmental Kuznets Curve: Evidence from developed and developing countries".** represents my original work required for the completion of PhD degree in Economics at the Quaid-I-Azam University, Islamabad and that it has not been formerly included in a dissertation submitted to this or any other institution for degree, except where due acknowledgement has been made in the text.

At any time if my statement is found to be incorrect, even after my graduation, then Quaid-I-Azam University, Islamabad has the right to withdraw my PhD degree.

Iqbal Hussain

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About the Author

Iqbal Hussain, son of the late Haji Muhammad Ghulam, was born in Thrai, Lower Dir, Pakistan. He completed his early education at Government Lower Middle School Thrai and Government High School Khazana, graduating with a matriculation in science from Government High School Timargara. He pursued his F.Sc. in Pre-Engineering and earned a B.Sc. in Mathematics and Computer Science from Government Degree College Timergara (now a postgraduate college) in Dir Lower. Later, he obtained an M.A. in Economics from the University of Peshawar, Khyber Pakhtunkhwa.

Iqbal began his career as a Certified Teacher (CT) teacher at GMS Meraki and GHS Shalkandi Dir (Lower), where he taught Mathematics and Physics. After three years, he was appointed as a lecturer in Economics through the then-NWFP Public Service Commission in 2007 and was subsequently promoted to Assistant Professor. Later, he was promoted to the Associate Professor through a competitive selection process by the Khyber Pakhtunkhwa Public Service Commission. Throughout his career, he has served in various remote colleges across the province, dedicated to promoting education at the graduate and intermediate levels.

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List of Abbreviations

BRICS	Brazil, Russia, India, China, and South Africa
EKC	Environmental Kuznets Curve
FEM	Fixed Effect Model
FDI	Foreign Direct Investment
CO_2	carbon dioxide,
CH_4	methane
GDP	Gross Domestic Product
HFCs	hydrofluorocarbons
GCCC	Gulf Cooperation Council countries
GHG	Green House Gases
GMM	generalized method of moments
GLS	Generalized Least Squares
LM	Lagrange Multiplier
MINT	Mexico, Indonesia, Nigeria, Turkiye
OECD	Organization for Economic Co-operation and Development
O_3	ozone
OLS	Ordinary Least Squares
H_2O	water vapors
IPCC	Intergovernmental Panel on Climate Change
PCA	Principal Component Analysis
PHH	Pollution Haven Hypotheses
PHL	Pollution Halo effect
PFCs	perfluorocarbons
PPP	Purchasing Power Parity
PHH	Pollution Haven Hypotheses
PHL	Pollution Halo Hypothesis
PLS	Pooled Least Squares
SPM	Suspended Particulate Matter
SF_6	Sulphur hexafluoride and
NGOs	non-governmental organizations
REM	Random Effect Model
USSR	Union of Soviet Socialist Republics
UNCCO	United Nation Framework Convention on Climate Change
WGI	Worldwide Governance Indicators
WDI	Worldwide Development Indicator

Chapter 1

INTRODUCTION

1.1 Background of the study

Over the past several decades, the global community has been facing multiple challenges including poverty, food security, environmental degradation and climate change. Of all the challenges, environmental degradation takes the central position because of various reasons. On one side environmental degradation is the consequence of economic growth achieved through industrialization, especially in newly developing countries where poverty rates and food insecurity have declined sharply. China in particular and India and Bangladesh to some extents have been able to reduce poverty through industrialization, mostly with the help of foreign direct investment but at the cost of increased industrial pollution.

On the other side of the picture environmental degradation is also a cause of climate change and its repercussions for natural disasters, health, food production, and poverty and food security. The fear is that the impact of economic growth on wellbeing that also causes environmental pollution may be offset by its adverse consequences in the form of climate change. These changes in environment are more disastrous to the poor or underdeveloped economies that have marginal contributions to pollution emission. Since, World Scientist Warning endorsed by 1700 experts in 1992 , there is 40 percent rough increased in greenhouse gases (Ripple et al., 2022).

Economic development has been sped up by increased the use of fossil fuels, which has accumulated the greenhouse gases, like Carbon Dioxide, Methane, Nitrous Oxides, Sulphur Oxides, water vapors, ozone O_3 Hydro Chlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs). Greenhouse gases, especially the increasing level of CO_2 emission, are considered the main drivers of global warming and climate change. It is well-known that the growing level of concentration of greenhouse gases near the earth surface are due to anthropogenic burning of fossils fuels. (Haines & Patz, 2004; Ring et al., 2012). The water vapors (H_2O), CO_2 and O_3 gases called infrared gases are present near the earth surface and absorb radiation then warm the atmosphere consequently the earth surface becomes hot, near the surface of earth atmosphere is become warmed. The IPPC argued that most of the surge in global warming is due to human activities since the 20^{th} century. (Ripple et al., 2022).

In brief, scientists are agreed that increase in the global warming is due to human activities including economic activities, especially with the transitions of producing goods to the machines have increased the greenhouse gases emission to the atmosphere. The human activities include production of goods and services through machines and transition of economy from agrarian and handicraft economy to industrial economy. Due to human activities the contamination of greenhouse gases and other unwanted things to the atmosphere is called environmental degradation. The presence of environmental degradation can be seen in the form of high global temperature, melting of glaciers, draughts, cyclones, floods, water pollution and deforestation across the continents. (Lau et al., 2023)

However, some hope was provided by the so-called Environmental Kuznets Curve. Following the concept of Kuznets Curve (Kuznets, 1955) that postulates an inverted U-shaped relationship between economic development and income inequality, environmental economists hypothesized that similar relationship exists between the economic development and environmental pollution (Grossman and Krueger, 1991, 1995; Panayotou, 1993, 1995; Selden and Song, 1994; and Stern et al., 1996; Stern, 2017) . When the economic development takes-off at initial stage, it is dominated by industrialization and intensive use of fossil fuels, and natural resources, which cause environmental pollution. At this stage emphasis is on raising income through production of goods and services and environmental protection is on the lower priority. However, once a certain level of economic development is achieved, the environment is also values and energy-efficient production techniques are invented and adopted that result in reduced pollution levels. However, once a certain level of economic development is achieved, regulations stir the economy towards energy-efficient. This inverted U-shaped relationship between economic development and pollution emission is known as Environmental Kuznets Curve (EKC).

In search for the empirical validity of EKC, researchers have applied various econometric quantitative. Questions on the existence of an empirical relationship between pollution and economic growth are evolving through examining the EKC hypotheses. These, studies have incorporated various ambient air contaminants, ecological footprints, influencing factors, water and soil pollutants for different data sets, and methodologies to prove or dissent with it. The contrasts in methodologies, specifications, explanatory variables and various other considerations, led to different empirical outcome of for the EKC hypothesis.

Evidence against the EKC hypothesis is mostly observed in underdeveloped and developing countries where economic development has not reached to the point from where onward pollution starts to decline. Hence in these economies the economic growth is preferred over conservation of the environment. Moreover, income elasticity of demand for environment is low (McConnell, 1997; Carson et al., 1997).

In contrast, the EKC hypothesis is by-and-large verified for high income and emerging economies. In these countries along with economic growth, social sectors development, strengthening of democracy and public awareness led to a consensus for environmental protection. Consequently, fossils fuels consumption is declining, renewable energy consumption is increasing, and the environmental deterioration is halted (Stern, 2017 Ansari, 2022; Isık et al., 2019; Shahbaz & Sinha, 2019; and Ulucak & Bilgili, 2018).

Literature also explores the role of governance in the context of environmental protection but to a limited extent. No study could be found that directly includes governance indicators as moderating factors in the context of EKC. Such an analysis can be useful not only in explaining the varied empirical evidence across countries but also in understanding the importance of governance in shaping EKC, particularly the location of its turning point.

Although a few studies have found evidence in favor of more simple or complex relation than the EKC relationship like a simple upward slopping or N-shaped relationship, there seems a lot more to be done in terms of introducing varying parameters in the EKC relationship to unfold the true underlying relationship between economic development and environmental pollution.

Another area of research revolves around the so-called Pollution Heaven Hypothesis (PHH) and its relationship with EKC. The hypothesis states that the by shifting their dirty industries to developing and emerging economies, the developed countries are essentially exporting their share of pollution to the other countries. In this context the role of FDI is explored in determining the level of environmental pollution and the placement and shape of EKC. However, this part of empirical literature also has a limitation as it considers the role of foreign direct investment inflows only and ignores the impact of already existing stock of foreign owned capital countries and time period.

1.2 Objectives of the Study

The above three paragraphs provide sufficient reasoning to expand the scope of research on environmental economics focusing on the following themes.

1. The role of governance in shaping the EKC;
2. Exploration of more flexible mathematical relationship between GDP and pollution than assumed in most of the literature; and
3. The relevance of foreign-owned stock of capital stock rather than foreign direct investment only in the study of PHH.

These themes are taken up in this thesis using a large data set covering 160 countries and 23 years from 1996 to 2018. The thesis is divided in three papers each covering one of the three themes.

1.3. Organization of the Study

In chapter 2, we explore the impact of governance on the location, slope, curvature and turning point of the EKC. This is done by specifying a simple quadratic relationship of the log of per capita CO_2 pollution with the log of per capita income and then making the three parameters of this relationship dependent on a governance index. In this way governance enters the EKC as a moderating factor. The results of this essay provide sufficient evidence to conclude that better governance practices are instrumental in achieving the goals of environmental protection.

In chapter we again start with a quadratic EKC in logs of per capita CO_2 pollution and per capita income and then allow the three parameters to change across various ranges of per capita income in such a way as to preserve continuity of the level and slope of the curve but allowing the second derivative to vary. This piece-wise regression, known as Spline Function, allow sufficient flexibility in the relationship and the empirical results indicate the presence of an M0-shaped or a double inverted U-shaped relationship.

Chapter 4 investigates the Pollution Haven Hypotheses in the EKC framework by focusing on foreign-owned capital stock rather than foreign investment inflow as the variable that matters in pollution emission. Two series of capital stocks are estimated using perpetual inventory method representing foreign-owned and domestically owned capital stocks. Then the ratio of foreign-owned capital stock to domestically owned capital stocks is computed. Finally, this capital ratio is introduced in the standard EKC as a moderating variable. The estimated relationship provides sufficient evidence to reject the PHH, a result that goes against the popular empirical evidence based on the data sets consisting of a large number of countries.

*Chapter 2

Curvature and Turning Point Environmental Kuznets Curve in a Global Economy: The Role of Governance

Abstract

Using a panel of 160 countries, this study explores the role of governance indicators in shaping Environmental Kuznets Curve (EKC). The study finds that better governance practiced tend to reduce CO_2 pollution, but the dividends of better governance are more pronounced in at higher income levels. The study further finds that better governance is also effective in bringing down the critical level of per capita income at which the relationship between income and pollution turns negative. The study concludes that good governance works only when the desired regulations are in place. Therefore, aid packages for governance reforms need to emphasize more on enactment of meaningful regulations than on their enforcement. Investment in institutions is expected to yield maximum dividends in such countries that have gained high income status but are still lacking in institutional development.

*Hussain, I., Ahmad, E., and Majeed, M. T. (2023). Curvature and turning point of the environmental Kuznets curve in a global economy: the role of governance. Environmental Science and Pollution Research, 30(18), 53007-53019. https://doi.org/10.1007/s11356-023-25835-7

2.1 Introduction

The inadvertent economic activities of humans on the planet are the main cause of producing by-products in the form of pollution. which has increased rapidly in the recent decades (Budyko, 1977). Pollution appears in many shapes like land pollution, water, air, noise, light, radiological pollution, etc. (CEF 2016). This study, however, mainly focuses on carbon dioxide emission, which contributes a major share to Green House Gas (GHG) emissions. Green HG that contains carbon dioxide (CO_2), methane (CH_4), hydrofluorocarbons (HFCs), Sulphur hexafluoride (SF_6) nitrous oxide (N_2O), and perfluorocarbons (PFCs), is mainly caused by the consumption of fossil fuels and other anthropogenic human activities (Reay et al., 2007). It is our necessity, as humans, to preserve the ecosystem not only for the present but for the future generations as well.

Pollution is a negative externality of the modern economic growth that diminishes waste recycling capacity of the environment. As a result of rapid economic growth, coupled with various emissions due to fossil fuel combustion in the modern industrial era, the environmental quality is prey to degradation. The unchecked emissions of GHG have a detrimental impact in the form of global warming, worsening of environment, melting of glaciers, increasing sea level, human health, marine life, and wildlife. In this regard various studies are launched to find out the exact relationship among the various environmental degradation indicators and per capita income. Among these, CO_2 emission is the premier indicator that is considered a responsible factor for the 76% of GHG emission and the resultant increase in global temperature. In the light of scientists' recommendations for sustainable environment, the Intergovernmental Panel on Climate Change (IPCC) vows to preserve the natural ecosystem and benefit people by limiting global warming to $1.5C^o$ rather than $2C^o$ (IPCC summary 2018; Burakov and Bass 2019). The voices for the protection of climate have led to the Kyoto protocol 1997 agreement, which was the first breakthrough towards mitigating emission by developed and developing countries. The Kyoto protocol put constraints on developed and developing countries to control the disastrous impacts of excessive use of fossil energy on the climate. The reduction in GHG emission is also included in the millennium development goals (Tarverdi, 2018) .

The issues of environmental pollution and degradation can be seen from Paris agreement in 2015,that was adopted by 196 countries. All articles especially from article1 to article 11 are stressing for reducing greenhouse gases and conserving environment. They significant points of the agreement are limiting global temperature rise to well below 2^0C above pre-industrial levels, with efforts to limit it to 1.5^0C. The agreements aim to achieve a balance between the greenhouse gas emission and removal in the second half of this century. The agreement allowed each country to establish National Determined Contributions (NDCs) to voluntarily set its frontier for reduction of emission. Apart from it developed countries will provide financial assistance to developing countries to tackle the mitigation and adaptations issues in developing countries (UNFCCC,2015).

The demand for clean and safe environment plays the role of normal good in consumer preferences. As income level in developed countries increases, the demand for cleaner environment increases, whereas low income countries are not so much fearful about environmental degradation(Lucas et al., 1992). The environmental economics literature reveals that if income elasticity of clean environment demand is positive then as GDP per capita increases, the demand for the protection of environment will also increase.

The above behavioral pattern is often represented by the so-called Environmental Kuznets Curve (EKC), a concept analogous to Simon Kuznets's theory of the inverted U-shaped relationship between economic development and income inequalities. According to the EKC hypothesis emission of environmental pollutants follows an inverted U-shaped relationship with the level of economic activity. This relationship states that at the initial phase with the increase in economic activity environmental degradation increase monotonically, reaching some threshold level after which environmental degradation falls with increase in economic activity (Grossman and Krueger 1991; Panayotou, 1993; Arrow et al. 1995; Cole, at al. 1997: De Bruyn 2002; M. Majeed, and Mazhar 2020; Farooq et al., 2022)

According to another explanation, in the early phase of industrialization, environment is badly effected due to the increased level of pollution because more importance is given to output of goods, employment and income than cleaner environment (Dinda 2004; Dasgupta et al., 2002). This process exhausts natural resource rapidly and due to low income of the people they are unable to pay the cost of avoiding such environmental losses. With further economic growth achieved, through industrialization, the living standards of the people rise and they start fearing about environmental losses. Institutions tend to come forward to confront pollution issues and intervene through regulations. On behalf of the public interest, these regulations bring pollution to lower levels.

To what extent this realization of the importance of clean environment translates into such practical steps that eventually result in cleaner environment depends on a country's ability to enact and implement effective regulations with consistency and accountability. These aspects of good governance are part and parcel of the very basic definition and concept of governance. A simple definition is the extent to which governments through their institutions legislate and implement their policies in the best interest of their citizens. According to Kaufmann et al.(2005) governance is the plural and inclusive concept, which is the outcome of joint activities, of non-profit sector, entrepreneurs , that represents a plan for sustainable development and quality of life.

The role of institutions in enforcement of environmental regulations for the protection of environment has been discussed in various studies from the very beginning due to interdependence between governance and environmental issues (Panayotou. 1997; López and Mitra.2000; Dasgupta et al.2002; Sohail et al. 2022). Since individuals cannot enact or enforce any regulations for environmental protection, this responsibility falls on state institutions that can step forward in public interest keeping in view the social benefits and costs of their actions. Hamilton et al. (2004) have added governance in the EKC analysis of environment and concluded that governance improvements can reduce the pollution significantly before a country reaches the middle income level. Kaufmann et al. (2005) studied the role of governance, considering its six individual indicators in controlling pollution. The role of governance in environmental protection has also been confirmed recently for BRICS countries by Baloch and Wang (2019), for Middle-Eastern and North African countries by Farzanegan and Markwardt.(2018), for 100 developed and developing countries by Lau et al. (2018), and for Asian Pacific countries by Ulucak (2020).

The present study contributes to the literature in the following ways: first, the study explores the role of governance in environmental protection following a different approach. Rather than just considering how governance can influence pollution along with other control variables. The study also allows governance to act as a moderating factor that can potentially alter the relationship between income and pollution. Thus the improvement in governance has assigned two roles. First the better governance can lead to a cleaner environment. Second, better governance can also influence the nature of the relationship between income and pollution. In particular, the study allows key parameters of the standard EKC to vary across different states of governance. In other words, governance is assigned the role of a moderating variable in the presumed quadratic relationship between per capital income and pollution. More specifically, the study explores whether better governance can make it possible to reverse the direction of a positive relationship between income and pollution at an earlier rather than later phase of economic growth. In other words, the explores the possibility of avoiding the negative externality of growth in terms of pollution emission at per capita incomes less than otherwise possible. Second, the study provides a global perspective employing sufficiently rich data containing broad variations in per capita income, emission level, and state of governance. All available panel data are used, which consist of 160 countries and 23 years (1996 to 2018).

The study attempts to answer the following questions. are three questions. First, can pollution be reduced systematically by adopting good governance practices in general? Second, is the effectiveness of good governance in reducing environmental pollution uniform across the whole range of low to high incomes? In other words, do the marginal improvements in the state of governance yield similar dividends among poor countries that tend to lie on rising portion of EKC as in rich countries that are expected to lie on the declining portion of EKC? Third, do the better governance practices enable various countries bring the turning point of EKC to lower levels of per capita income? In other words, can negative externality of rising per capita income in terms of environmental pollution be mitigated at earlier stage of development by adopting good governance practices?

Addressing the above questions requires sufficiently rich data containing broad variations in per capita income, emission level and state of governance. Therefore, all available panel data are used, which consists of 160 countries 23 years (1996 to 2018). The rest of the paper is organized as follows: A brief review of the relevant literature in the "Literature review section" is followed by methodology in "methodology" section. Data, variables construction and estimation procedure are described in the "Data and estimation procedure" section, while the results are presented in the "Results and discussion" section. Finally, the study is concluded in the "Conclusion and policy recommendations" section.

2.2 Literature Review

The empirical relationship between environmental indicators and per capita income was first explored in three contemporary and independent studies by Grossman and Krueger (1991), Shafik and Bandyopadhyay. (1992)and Panayotou (1993). The three studies found inverted U-Shaped relationship between some proxy of environmental pollution and per capita income. This relationship was termed Environmental Kuznets Curve (EKC) in Panayotou (1993) because of the analogy with Kuznets Curve (Kuznets, 1955).

Following this initial work, the possible existence of EKC in various sets of countries has been explored with a variety of data sets and econometric techniques. For example, Selden and Song (1994) employed panel as well as cross-sectional data and found evidence in support of EKC hypotheses. However, they observed that the turning points of per capita income for certain categories of emission are higher than those found in previous studies and warned that the overall level of pollution is still expected to rise in future. Roberts and Grimes (1997) studied the relationship of CO_2 emission and GDP growth for 147 countries for the period 1965-1990. While the study confirmed the presence of EKC for the developed countries, it found monotonic positive relationship between income and pollution in developing countries.

Research on the nature of relationship between emission and income (including EKC) has been extended in various directions such as the consideration of various pollution indicators and the roles of energy intensity, trade openness, foreign direct investment, industrial structure (sector-wise composition of the economy) and financial-sector development (see, for example, Omisakin and Olusegun.2009; Acaravci and Ozturk, 2010; Gani, 2012; Onafowora and Owoye, 2014); Farhani et al., 2014; Abid, 2016; Balogh and Jámbor, 2017; Bokpin, 2017; Ang, 2007; Jabeur and Sghaier, 2018; Ahmad and Majeed, 2019; Ahmad and Majeed, 2022; Ullah et al., 2021). The emperical evidence in Bekun, (2022) indicates that CO_2 pollution in India can be reduced significantly through the replacement of fossil fuel energy with renewable energy. The study alsoobserved that the current investment in the energy sector appears significantly environmentally friendly.

Several studies have explored the role of governance in controlling environmental pollution with mixed findings. Using data for 16 Middle-Eastern and North-African countries, Jafari, et al. (2012) observed that improvements in government effectiveness tend to reduce environmental degradation, while the impacts of regulatory quality and control of corruption are ambiguous. Similarly, Rockström et al., (2013) observed that the absence of rule of law, control of corruption, transparency and accountability have contributed to environmental degradation. More recently, Swain et al., (2020) observed on the basis of evidence from 58 non-OECD countries that control of corruption is effective in improving the environmental quality. This result confirms the earlier finding of Desai,(1998), Fredriksson and Svensson (2003), Cole (2007) and Sahli and Rejeb, (2015) that increase in the level of corruption leads to further degradation of the environment.

In another comprehensive study for 99 developing countries, Gani. (2012) concluded that good governance indicators; specifically, political stability, rule of law, and control of corruption; have negative impacts on the CO_2 emission. Similar conclusions are drawn in Esfahbodi et al. (2017) for the UK and Bokpin (2017) for African region and Jabeur and Sghaier (2018) for Middle-Eastern and North-African countries.

In a recent study based on panel data of 35 countries from different income groups, Güney, (2022) found that good governance can be instrumental in reducing CO_2 emissions through the adoption of solar energy generation. (Baloch andWang, 2019) also found support for the favorable effect of improvement in governance on CO_2 emission in BRICS countries. For South Asian countries in Zakaria and Bibi (2019) and Ashraf et al. (2022), for 38 Sub-Saharan countries in Sarpong and Bein (2020), for 93 emerging and developing countries in Wawrzyniak and Doryń (2020), and more recently for Saudi Arabia in Sarwar & Alsaggaf (2021).

The above discussion shows that good governance appears as an important tool for addressing the issue of environmental pollution. A few empirical studies (Laegreid and Povitkina 2018 ;Wang et al.2018; Wawrzyniak and Doryń 2020) have analysed the potential moderating effects of good governance on environmental pollution and found some encouraging results. However, these studies did not address the role of governance on environmental pollution in shaping the EKC. The role of governance in this context is still appears underexplored. In particular, it is not clear whether good governance is effective in controlling pollution at all levels of income and can good governance help reverse the rising trend of environmental pollution in relatively low-income countries or whether we still have to wait till such time these countries catch-up with middle to high income countries. In other words, there is a need to explore the role of governance in changing the shapes of the EKC, in particular, the location of its turning point.

2.3 Methodology

Before bringing governance into the EKC equation, it is important to understand the operational concept of governance and its measurement. According to World Bank reports (Kaufmann et al., 2011; Kaufmann and Kraay, 2008) two indicators of governance namely "Government Effectiveness" and "Regulatory Quality" are developed to measure government's capacity to formulate and implement sound policies. Another two indicators, "Rule of Law" and "Control of Corruption" are aimed at measuring respect for the institutions that govern economic and social interactions across citizens and state. Finally, two more indicators "Voice and Accountability" and "Political Stability and Absence of Violence" measure the quality of process by which governments are selected, monitored, and replaced.

While Government Effectiveness is important for the formulation of environmental protection policies, Regulatory Quality, Rule of Law and Control of Corruption are important for implementation, enforcement, and acceptance/respect of these policies by public and state organs. However, any indicator of good governance does not by itself guarantee cleaner environment unless clean environment occupies an important place in the manifesto of a political party (or any other group or dictator) holding power to govern a country. In developed countries clean environment is valued more highly by citizens and, hence, by political parties (or any other aspirants of power), as compared to developing countries where eradication of poverty, raising standards of living and development of infrastructure and human development facilities are given prime importance. In other words, good governance is less likely to yield dividend in the context of environment in developing countries where public policy does not critically focus on environment and there are not many such policies in place that are to be implemented and enforced.

The above discussion provides a basis for introducing governance in EKC as a moderating factor that enters the equation in interactive form with income. A few earlier attempts in this direction(e.g. Laegreid and Povitkina 2018 ;Wang et al.2018; and Wawrzyniak and Doryń 2020) have allowed the moderating role of governance in the GDP-CO_2 relationship either in linear setting or by splitting date between sets of countries having high-and low-quality institutions on environmental pollution and found encouraging results. However, the present study addresses the role of governance in shaping EKC by making all parameters of the curve to be potentially sensitive to the state of governance.

Representing the state of environment by per capita CO_2 emission and the level of economic activity by per capita income, denoted by CO_2 and Y respectively, we start with the following standard quadratic equation in logs underlying the EKC equation (Eq.1):

$$log\,CO2 = \alpha + \beta\, log\, Y + \delta\, log\, Y^2 + U \quad (1)$$

The location and shape of EKC depends on the three parameters present in the equation. To bring-in the role of governance, these parameters are allowed to vary systematically with the state of governance, denoted by G, as follows.

$$\alpha = \alpha_0 + \alpha_1\, G \quad (2a)$$

$$\beta = \beta_0 + \beta_1\, G \quad (2b)$$

$$\delta = \delta_0 + \delta_1\, G \quad (2c)$$

Finally, substituting right hand sides of equations (2a) (2b) and (2c) in equation (1), yields:

$$log\,CO2 = (\alpha_0 + \alpha_1\, G) + (\beta_0 + \beta_1\, G)\, log\, Y + (\delta_0 + \delta_1\, G)\, log\, Y^2 + U \quad (3)$$

EKC hypothesis is verified if the rate of change in CO_2 emission is positive up to certain level of per capita income, say Y^* and negative thereafter. The critical level Y^* is the turning point in the inverted U-shaped relationship in EKC. Thus, consider the first and second derivatives of the expected value of log $CO2$ with respect to logY

$$\frac{\partial(log\,CO2)}{\partial\, log\, Y} = \beta_0 + \beta_1\, G + 2\,(\delta_0 + \delta_1\, G)\, log\, Y \quad (4)$$

$$\frac{\partial^2(log\,CO2)}{\partial(log\,Y)^2} = 2\delta_0 + 2\delta_1\, G \quad (5)$$

The turning point of EKC, given below, is the level of per capita income at which the first derivative is equal to zero. Solving equation (4) for $logY$ as per first order condition

$$\log Y^* = -\frac{1}{2}\frac{\beta_0 + \beta_1\, G}{\delta_0 + \delta_1\, G} \quad (6)$$

Finally, the turning point responds to changes in the state of governance as follows.

$$\frac{\partial \log Y^*}{\partial G} = \frac{1}{2}\frac{\beta_0\delta_1 - \delta_0\beta_1}{(\delta_0 + \delta_1\, G)^2} \quad (7)$$

It can be seen from equations (3) to (7) that the location, slope, and curvature of the

EKC all depend on the state of governance. The EKC hypothesis will prevail if $\beta_0 + \beta_1\, G > 0$ and $\delta_0 + \delta_1\, G < 0$ at all levels of governance indicator. Furthermore, the turning point in EKC also depends on the state of governance and in what direction it varies with the improvement in governance depends on the signs and magnitudes of the four parameters appearing in equation (7). Based on discussion at the beginning of this section, the signs of various parameters are expected to be as follows.

$\alpha_0 < 0,\ \beta_0 > 0,\ \beta_1 > 0,\ \delta_0 < 0,\ \delta_1 < 0$

Finally, to avoid possible specification bias, Eq. 3 is extended to include other(control) variables in the model. Although the literature proposes quite a few potential control variables, we consider four of them on the basis of overwhelming evidence. For example, using a dynamic global simulation model, Koch and Kaplan.(2022) showed that restoring even half of the potential forest area can account for 56 to 69% of the carbon storage. In another global study, Lawrence et al.(2022) found that the net cooling effect of forests (the net of biophysical and biochemical effects) is substantial, which also include favorable spatial spillover effects. Similar results are reported by Li et al.(2021) for 30 provinces in China.

Muhammad et al. (2020) analyzed the effects of trade on CO_2 emission and found that these effects statistically significant, though their signs and magnitudes can vary across income groups. Meng et al., (2018) observed that export-led-global CO_2 emission has surged because of the emerging global supply-chain trends that tend to rely on the developing south for the production of energy-intensive raw materials and intermediate goods.

Literature also indicates that production activity in different sectors of the economy is not equally energy intensive and may face different sets of environmental regulations. For example, using a panel of 94 middle-income countries, Sebatian et al. (2022) found a negative relationship between CO_2 emissions with agriculture value added for any given level of GDP. Similar results are reported in Khurshid et al.(2022) for Pakistan. However, Eisen and Brown.(2022) found that livestock production has a substantial adverse impact on the environment through methane and nitrous oxides. Similarly, the contribution of manufacturing output to pollution is well documental (see, for example, Liu et al. 2019) and Stavropoulos et al. 2022 for a recent account).

Based on the above discussion, Eq. (3) in the following general form for econometric application with panel data, wherein Forest, Trade and Agr denote the proportion of geographic area covered under forests, trade openness (export plus import to GDP), and the shares of manufacturing and agriculture outputs in GDP, respectively. The subscripts *i* and *t* are country and period (year) identifiers (see Eq. 8).

$$log\,CO2_{it} = \alpha_0 + \beta_0\,log\,Y_{it} + \delta_0\,log\,Y_{it}^2 + \alpha_1\,G_{it} + \beta_1\,G_{it}\,log\,Y_{it} + \delta_1\,G_{it}\,log\,Y_{it}^2 + \theta_1\,Forest_{it} + \theta_2\,Trade_{it} + \theta_3\,Man_{it} + \theta_4\,Agr_{it} + \lambda_i + \phi_t + \varepsilon_{it} \qquad (8)$$

Note that λ_i and ϕ_t represent the country and period effects that can be deterministic or stochastic components. If λ_i are treated as deterministic (stochastic) components, the model is referred to as country Fixed (Random) Effects model. Similarly, deterministic (stochastic) treatment of the components ϕ_t is akin to period Fixed (Random) Effects model.

2.4 Data and Estimation Procedure

Since data on governance indicators are not available for sufficiently long period, the study relies on panel data for the period 1996 to 2018. A sample of 160 countries is selected for which the required data are almost available over the entire period. A few missing values are filled by inter/extrapolation.

Environmental pollution is approximated by per capita CO_2 emission, while income variable is represented by per capita GDP. The data on CO_2 emission are in million tons, which are converted to kilograms before expressing the variable in per capita terms. For valid international and over time comparison, the data on GDP are taken in constant PPP 2011 US dollars.

Governance index is computed based on four governance indicators: Government Effectiveness, Regulatory Quality, Rule of Law; and Control of Corruption which are constructed to measure government's capacity to formulate and implement public policies and to ensure that their enforcement is respected by public and state organs. The last two indicators, Voice and Accountability and Political Stability and Absence of Violence are not included. The reason is that in many developing countries democracy has not taken roots and as a result democratically elected governments may not necessarily show better governance records on effectiveness and implementation of policies even though they may show moderate governance score on how governments are selected, monitored, and replaced.

The governance indicators are scaled -2. 5 (the worst state) to 2.5 (the best states). Since all the four indicators are highly correlated, their direct inclusion in the regression equation will most probably distort parameter estimates due to multicollinearity. In such a situation, it makes sense to combine all the indicators into a single index. This index is calculated using Principal Component Analysis (PCA) and is linearly normalized on zero to one scale.

Data on CO_2 emissions are taken from *Global Carbon Project*, while the data on the six governance indicators are collected from *Worldwide Governance Indicators* (*WGI*). The data on all the remaining variables including GDP, population, forest area as a proportion to total area, trade openness and the shares of agricultural and industrial sectors in GDP are taken from *World Development Indicators* (*WDI*).

A variety of empirical modelling and estimation strategies are available, and each one has its specific merits. Generally, a pooled least square model in which all the fixed and random effects are absent yields poor results unless the sample size including the cross sectional and time dimensions are small. Fixed and random effects model are aimed to account for observational heterogeneity. In case where cross-sectional units are chosen randomly, the heterogeneity can be attributed to random sampling, and in this case, random effects models are preferred. However, when cross sectional units are chosen systematically, as we have done by including all the countries on which data are available, fixed effects models have more appeal because data are expected to vary across countries systematically.

In the presence of inertia in the dependent variable and autocorrelation in errors, the above models produce biased results both in small and large samples, and the preferred estimation technique is the generalized method of moments (GMM).
Other modeling strategies motivated by time-series econometrics are suitable when the number of periods is large, if not greater than the number of cross-section units. These options are not considered here because of the small period of analysis (23 years).

The possible presences of fixed and random effects in Eq. (8) are tested using

Wald and Lagrange Multiplier (LM) tests respectively. In case the presence of both cannot be rejected, the choice between the two types of effects can be made on the basis of Housman and Wu test. While the model containing fixed effects in the absence of autocorrelated errors can be estimated by OLS, the one containing random effects is to be estimated by iterative feasible Generalized Least Squares (GLS) method.

Table 2. 1: correlation matrix

	$LogCO_2$	**LogY**	**G**	**Forest**	**Trade**	**Man**	**Agr**
$LogCO_2$	1	0.916	O.609	-0.072	0.284	0.227	-0.802
LogY	0.916	1	0.711	-0.022	0.304	0171	-0.833
G	0.609	0.711	1	-0.008	0.143	0.029	-0.597
Forest	-0.072	-0.022	-0.008	1	0.070	-0.046	0.011
Trade	0.284	0.304	0.143	0.070	1	-0.017	-0.248
Man	0.227	0.171	0.029	-0.046	-0.017	1	-0.203
Agr	-0.802	-0.833	-0.597	0.011	-0.248	-0.203	1

It is highly probable that CO_2 follows time inertia and therefore, one-year lagged CO_2 may be included on right side of the equation. This variable suffers from endogeneity problem if the country effects λ_i are treated as random variables or the general random error term U_{it} is autocorrelated. If this happens, the appropriate estimation technique will be Generalized Method of Moments (GMM).

As usual the choice of instruments for the GMM estimation is a tricky matter and at least two considerations are important in this respect. First, there should be sufficient number of instruments to gain incremental precision as compared to Two-Stage Least Squares estimates. But too may instruments can create artificially strong relationship. Standard practice is to use time-specific instruments proposed in (Arellano & Bond, 1991). These instruments are derived on the moment condition that lagged dependent variable with two or higher period lags are orthogonal to random errors in each period available for estimation.[1] Unlike the single time series data, panel data provide as many observations as the number of cross-sectional units (countries in our case) for each single period. Therefore, as proposed in Arellano and Bond (1991), it is possible to general quite a few instruments if the orthogonality

[1] The choice of lag 2 is based on the assumption that the error term in first difference form $\Delta\varepsilon_{it}$ has non-zero autocorrelation at first lag but zero autocorrelation at higher lags, which means that the original random error ε_{it} has no autocorrelation at any lag. To this end Arellano-Bond tests of autocorrelation in $\Delta\varepsilon_{it}$ are applied to confirm that the null hypothesis of zero first order autocorrelation is rejected, while the null hypothesis of zero second order autocorrelation is not rejected.

conditions are applied period by period. Additional instruments can also be made available by using similar dynamic structure or simple static structure on the moment conditions on the other variables appearing on right-hand side of the equation.

The second consideration in the choice of instrumental variables concerns validity of the instruments, which is addressed by applying Sargan's test using J-statistic (based on the original work of Sargan (1958). If the number of instruments is barely minimum (equal to the number of parameters), the sample moment conditions are exactly satisfied and GMM collapses to (simple) Method of Moments, which leaves nothing to test for the validity of moment conditions. The advantage of GMM lies in having excess instruments or over-identifying moment conditions in which case all the sample moment conditions cannot hold simultaneously and their validity is tested in statistical sense.

2.5 Results and Discussion

Before estimating the proposed regression model PCA is used to construct the governance index. The analysis reveals that the first Principal Component alone accounts for 94.35% common variation in the four governance indicators. Therefore, construction of a single index appears sufficient, and the other orthogonal dimensions of data can be safely ignored.

Table 1 and Table 2 show the correlation and variance inflation factors (VIF), which indicate that despite high correlation in two pairs of independent variables. There is no serious problem of multicollinearity in data as indicated by VIFs. This is because of the overall large sample size (3680 observations) used in the estimation.

Table 2. 2: **variance inflation factors**

Log Y	G	Forest	Trade	Man	Agr
4.497	2.092	1.009	1.131	1.072	3.313

Estimation of equation (8) is done in various rounds to ensure robustness. Initially it is estimated with country and period fixed effects and Wald test is applied to test two null hypotheses one by one; that is a) country fixed effects are jointly equal to zero, and b) period fixed effects are jointly equal to zero. The model is then estimated with country and period random effects and LM test is applied to test null hypotheses that a) country random effects are equal to zero, and b) period random effects are equal to zero. The two regression results are presented in the second and third columns of Table 3. In both the cases while the absence of period (fixed or random) effects cannot be rejected, the absence of country (fixed or random) effects is rejected. This result rules out pooled Least Square estimation on account of significant country effects. The two models are then restricted by excluding the period (fixed and random) effects and the results are shown as country Fixed Effects Model and country Random Effects Model in the fourth and fifth columns of Table 3.

Table 2. 3: Regression Results Based on Fixed and Random Effects Models *(*Dependent variable is log per capita CO_2)

Independent variables	Model Type					
	County-Period FEM	Country-Period REM	Country FEM	Country REM	County-Period FEM	Country FEM
Intercept	-0.1131 (-0.03)	0.0836 (0.05)	-2.3068 (-1.51)	-2.2573 (-1.54)	-0.7683 (-0.54)	-0.508 (-0.36)
Log per capita GDP (*Y*)	1.5196 (1.6)	1.4954 (4.29*)	1.8371 (5.28*)	1.8355 (5.5*)	0.544 (1.7***)	0.537 (1.67***)
Log per capita GDP square (Y^2)	-0.0667 (-1.27)	-0.0669 (-3.35*)	-0.0789 (-3.96*)	-0.0796 (-4.17*)	-0.0255 (-1.39)	-0.028 (-1.52)
Governance index (*G*)	-26.6349 (-3.06*)	-26.9005 (-8.18*)	-24.0152 (-7.23*)	-23.9909 (-7.54*)	-6.7925 (-2.2**)	-7.1555 (-2.31**)
Governance index multiplied by log per capita GDP (*G*Y*)	5.4709 (2.92*)	5.5594 (7.69*)	4.8044 (6.6*)	4.8089 (6.9*)	1.4014 (2.07**)	1.504 (2.21**)
Governance index multiplied by log per capita GDP square ($G*Y^2$)	-0.2772 (-2.75*)	-0.2833 (-7.13*)	-0.2338 (-5.87*)	-0.2343 (-6.14*)	-0.0713 (-1.92***)	-0.0777 (-2.08**)
Proportion of area covered under forests (*Forest*)	-1.3235 (-1.85***)	-1.2582 (-5.05*)	-0.8414 (-5.36*)	-0.8287 (-5.52*)	-0.5617 (-2.41**)	-0.4706 (-2.04**)
Trade as ratio to GDP (*Trade*)	-0.0141 (-0.27)	-0.0175 (-0.73)	-0.0109 (-0.45)	-0.0139 (-0.6)	-0.0027 (-0.12)	-0.0065 (-0.29)
Share of manufacturing sector in GDP (*Man*)	0.059 (0.27)	0.1005 (0.74)	0.3864 (2.8*)	0.421 (3.2*)	-0.0894 (-0.72)	-0.0301 (-0.25)
Share of agricultural sector in GDP (*Agr*)	-0.6276 (-1.6)	-0.5573 (-3.85*)	-0.6308 (-4.25*)	-0.5967 (-4.22*)	-0.5516 (-3.96*)	-0.4974 (-3.7*)
One-year lagged CO_2					0.767 (33.82*)	0.7615 (33.51*)
R-squared	0.9763	0.9760	0.3236	-0.5967	0.9823	0.9820
Adjusted R-squared	0.9750	0.9749	0.3219	0.3274	0.9813	0.9811
F-statistic	754.90	851.10	195.06	199.96	970.31	1080.18

Note: The t-statistics (presented in parenthesis) significant at 1%, 5% and 10% levels are indicated by *, ** and *** respectively.

At the next step, Hausman and Wu test is applied to make a choice between Fixed and Random Effects Models and the test results support the former model against the latter one.

In all the estimated equations significant first order autocorrelation in errors is found to be present, which calls for the inclusion of lagged dependent variable on right side of the equation. Since country random effects are time invariant, these are by construction correlated with lagged dependent variable (just as they are correlated with the current dependent variable) and the most appropriate estimation technique in this case is GMM. Regarding fixed effects estimation, the results are valid if inclusion of lagged dependent variable removes autocorrelation from errors. The last two columns of Table 1 show that this is not the case and significant autocorrelation persists and the recommended estimation technique is again GMM.

Table 4 presents the results of two rounds of GMM estimation based on equation (8) converted to first difference form (in order to drop out the fixed or random country effects). In GMM-I estimates the set of time specific instruments as proposed in Arellano and Bond (1991) are used (that is, two-period lag of dependent variable with orthogonality condition applied period by period). In GMM-II estimation, in addition to Arellano and Bond's instruments, two-period lags of all the variables appearing on right-hand side of the equation are also used with orthogonality condition applied to the entire sample rather than on a period-by-period basis (that is, the static structure on the moment conditions).

Table 2. 4: Regression Results Based on GMM (Dependent variable is log per capita CO_2)

Independent variables	Model Type	
	GMM-I	GMM-II
Log per capita GDP (*Y*)	1.8369 (27.1*)	1.2084 (10.58*)
Log per capita GDP square (Y^2)	-0.0911 (-22.82*)	-0.056 (-8.45*)
Governance index (*G*)	-2.4349 (-5.16*)	-5.4159 (-8.84*)
Governance index multiplied by log per capita GDP ($G*Y$)	0.6674 (6.72*)	1.3643 (9.73*)
Governance index multiplied by log per capita GDP square ($G*Y^2$)	-0.0474 (-8.88*)	-0.0867 (-10.65*)
Proportion of area covered under forests (*Forest*)	-0.1889 (-3.5*)	-1.1087 (-19.5*)
Trade as ratio to GDP (*Trade*)	-0.1402 (-62.58*)	-0.1391 (-52.65*)
Share of manufacturing sector in GDP (*Man*)	0.2333 (5.57*)	0.1205 (3.98*)
Share of agricultural sector in GDP (*Agr*)	-1.4702 (-67.13*)	-1.4876 (-63.78*)
One-year lagged CO_2	0.4855 (203.16*)	0.4774 (167.92*)
J-statistic	159.04	152.18
Prob(J-statistic)	0.31	0.46

Note: The t-statistics (presented in parenthesis) significant at 1%, 5% and 10% levels are indicated by *, ** and *** respectively.

A few observations from Tables 3 and 4 are notable. First, the results seem remarkably robust across alternative estimation techniques as far as signs of regression coefficients are concerned. In all the eight estimates presented in the two tables the signs of regression coefficients of the five key variables under focus (log per capita GDP, square of log per capita GDP, governance index, governance index interacting with log per capita GDP and governance index interacting with square of log per capita GDP) remain the same with no exception. The signs of regression coefficient of control variables also remain the same with two exceptions with the signs of the share of manufacturing sector in GDP. Both the exceptions occur in the two Fixed Effects Models with lagged dependent variable, which are in any case not as reliable as the GMM estimates.

Second, the statistical significance of the parameter estimates is also reasonably consistent. As expected, the most significant results are obtained under GMM estimation in which all the parameter estimates are highly significant. On the other hand, the least number of significant coefficients are estimated with Fixed Effects Model with country and period fixed effects but no lagged dependent variable, followed by Fixed Effects Models with lagged dependent variable. The possible reasons could be the presence of the large number of fixed effects and additionally the presence of lagged dependent variables, which collectively suck most of the variation in the dependent variable leaving not enough variation to be explained by other variables. The trade openness variable appears significant only in GMM estimates.

In any case, the consistency of results means that we can focus on and discuss in detail the estimation results obtained from the most appropriate technique, GMM, which also produces the most significant relationship. Specifically, the following discussion is based on the results of GMM-I model, which employs time-specific instruments proposed in Arellano and Bond (1991).

Since the relationship of CO_2 emission with income and governance variables is non-linear, there is no sense in interpreting each regression coefficient in a typical way to mean partial effect. All we can say is that the signs and significance of parameter estimates make sense. For example, if governance level is held constant at the lowest level (equal to zero), CO_2 emission is observed to increase with per capita income at diminishing rate up to some point after which the relationship turns negative. It is possible to draw similar conclusion at other level of governance above the minimum level.

Figures 1(a) and 1(b) display sets of EKCs at the extreme levels of governance index (zero and one) and at all its nine decile points. In the first figure variables are measured in logs, while in the second one they are measured in levels. While drawing these figures all the variables other than per capita income and governance score are set equal to their sample mean values. In each figure the highest (lowest) curve corresponds to the lowest (highest) governance score, which is equal to zero (one) and the inverse relationship between governance and CO_2 emission remains monotonic throughout the range of governance index. This observation affirms our first research question, that is, does good governance contribute to reducing pollution systematically?

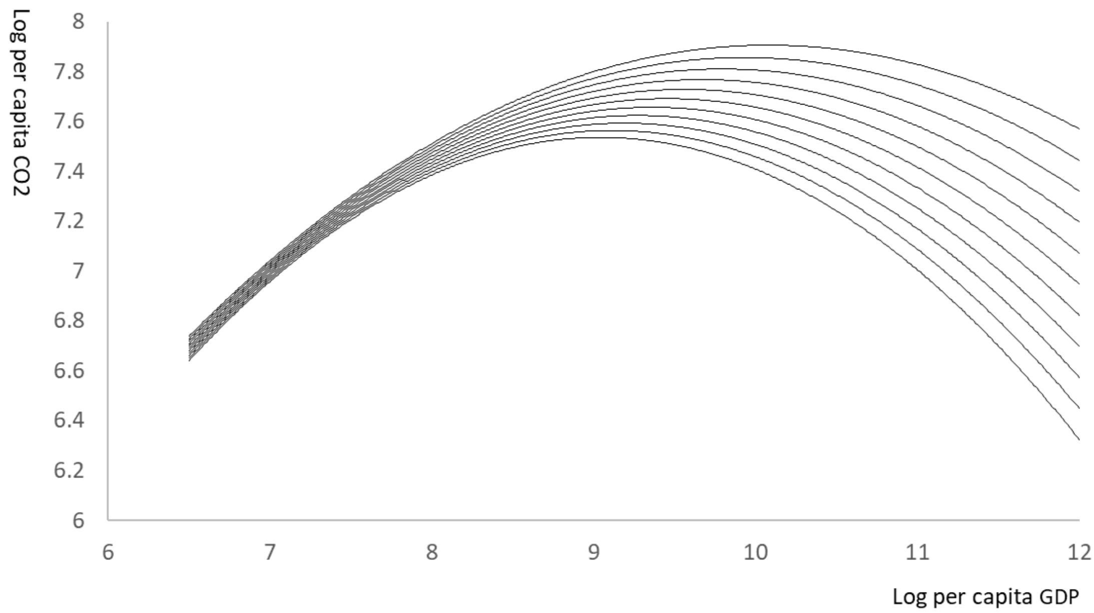

Figure 2.1 1: EKCs in Log Per Capita Terms at Alternative Governance Levels

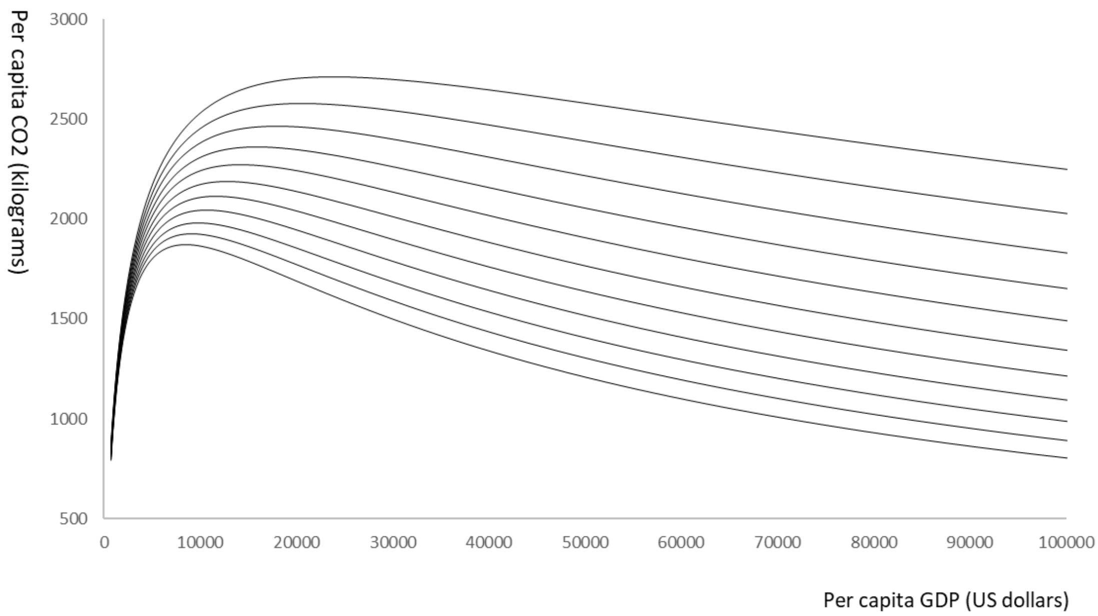

Figure 2.1 2: EKCs in Per Capita Terms at Alternative Governance Levels

However, the two figures also show that the shifts in EKC resulting from better governance levels are neither uniform, nor proportional to the location of the curve with respect to the per capita income. Thus, the answer to our second research question, that is, does good governance help reducing pollution at all income levels in a uniform way, is negative. The figures show that gap between the EKCs representing any two governance scores widens as we move along the curve from left to right implying that good governance brings more fruitful results in high-income countries as compared to low-income countries. Figure 2 further illustrates this point by drawing the relationship between log per capita income and the percentage reduction in per capita CO_2 when the governance scores in increased from 20 to 80 percentile points. The curve is almost flat in the low-income range that prevails in low-income countries or the low-middle income countries lying in low-income range where the predicted reduction in CO_2 emission is very low, around 5%. However, the percentage reduction in pollution becomes larger at higher income levels, reaching up to 50% at the highest income level in the given data.

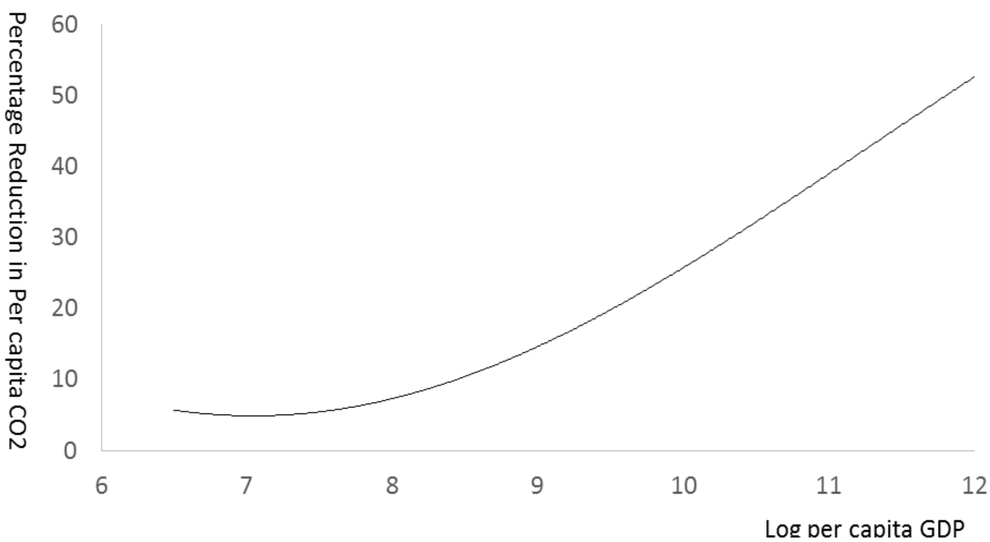

Figure 2.2. 1: Percentage Reduction in Per Capita CO_2 Emission Resulting from Improvement in Governance Score From 20 To 80 Percentile

Regarding the third research question, it is confirmed from Figures 1(a,b) that the critical level of per capita income at which the relationship between income and pollution turns negative is inversely correlated with the governance index. This relationship is further illustrated through Figure 3, which shows that the increase in governance index between 20 and 80 percentage points is associated with about 45% reduction in the critical level of per capita income. This is an overwhelming evidence to support the proposition that better governance practices enable various countries bring the turning point of EKC to lower levels of per capita income. Thus, if most of the countries follow good governance standards, world can reverse the negative spillover of economic growth on environment at lower level of income than otherwise predicted.

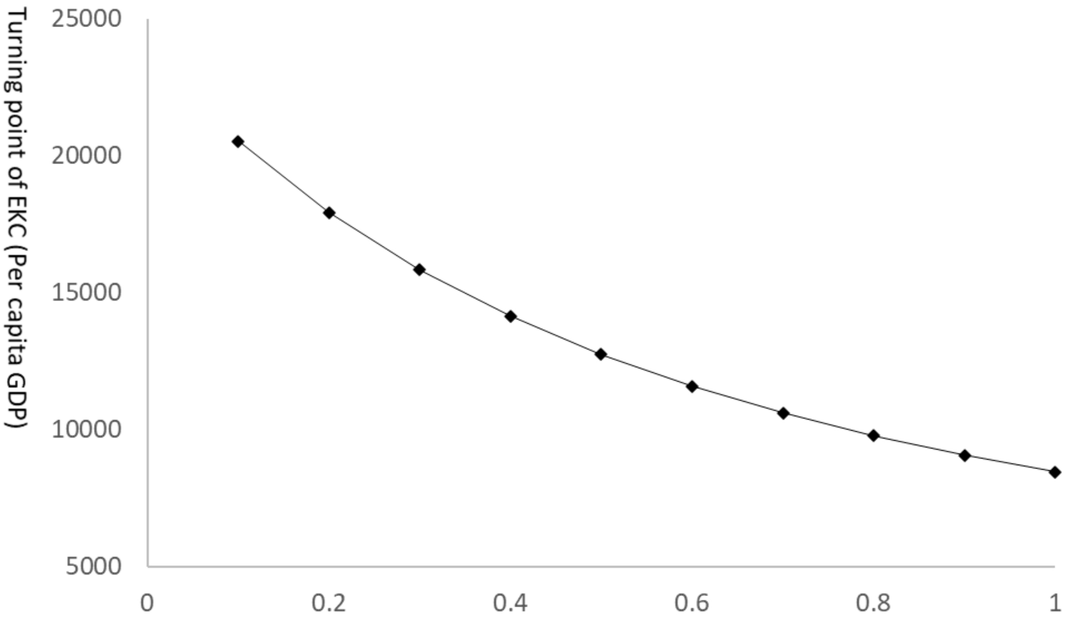

Figure 2. 1: Relationship between Governance Score and Turing Point of EKC

The effects of control variables on pollution are found to be according to expectations. The first variable, the share of geographic area covered under forests, is negatively and significantly correlated with pollution. Each one percentage point reduction in forest area can be associated with 0.19 percent increase in per capita CO_2 emission. This is an expected result because deforestation is known to be a reason for CO_2 emission and the related environmental consequences. The next control variable is trade openness, which is also found to be negatively and significantly correlated to pollution as each one percentage point increase in trade openness is associated with 0.14 percent reduction in per capita CO_2 emission. The countries with higher trade volumes have to adopt relatively more efficient modern production techniques that tend to conserve energy use and adopt environment protection measures that in turn result in lower pollution (Majeed et al., 2022; Tahir et al., 2021).

Since the regression model includes the shares of both manufacturing and agricultural sectors in the equation, an increase in any of these shares will be at the cost of the reduced share of rest of the economy, which essentially means the share of services sectors. The results show that per capita CO_2 emission is positively correlated with the share of manufacturing and negatively correlated with the share of agricultural sector and both the relationships are statistically significant. This essentially means that compared to services, manufacturing activity is more pollution-intensive, whereas agricultural activity is less pollution-intensive. This result is also according to expectations because the production activity in manufacturing sector is by-and-large more energy intensive and that in agricultural sector is less energy-intensive.

Although no empirical work is found that explores the role of governance in the context of EKC the way the present study done. It is still possible to compare our results with some of the earlier findings. Lægreid and Povitkina (2018) observed that the moderating role of the control of corruption is crucial. Wawrzyniak & Doryń (2020) could not confirm the moderating role of control of corruption and observed a significant reduction in CO_2 emission in the countries with high government effectiveness in some but not all specifications of the model. Lægreid and Povitkina (2018) also found that the adverse effect of GDP per capita on CO_2 emission is not profound in rich well-governed countries but the moderating effect of institutions is small. The present study, on the other hand, finds overwhelming support for the moderating role of the governance index. For the reason that, it allows all parameters of the EKC to vary across different levels of the governance index. It is also noted that this relationship remains robust across eight different modelling options for panel data regressions.

2.6 Conclusion and policy recommendations

Using a panel data set for 160 countries and 23 years, this study analyzes the role of institutions in determining how pollution can be related to the pace of economic activity. The study finds that the level of pollution can be systematically reduced by adopting good governance practices. However, returns to better governance in terms cleaner environment are found to be higher at higher income levels, increasing exponentially with the increase in per capita incomes. Finally, it is observed that better governance is effective in bringing down the critical level of per capita income at which the relationship between income and pollution turns negative.

The Following conclusions are drawn from the above results. In low-income countries, better governance seems to yield negligible environmental outcomes not only because the direct impact of governance on pollution is very small but also because their per capita income levels remain well below the critical level at which the relationship between income and pollution turns negative even after governance score is increased up to the maximum possible level. Good governance remains ineffective largely because the focus of institutions in these countries is not as much on environment as on other pressing issues like infrastructure, human development, and poverty. Good governance in developing countries will only when the desired regulations are in place. Therefore, aid packages for governance reforms need to emphasize more on enactment of meaningful regulations than on their enforcement.

Second, although rising per capita income in low middle-income countries is expected to result in increased pollution in the coming years, this undesired consequence of economic growth can be counterbalanced by investment in institutions to yield better state of governance. In such countries the direct impact of better governance on environment is small, but the main advantage comes from the role of governance in reversing the relationship between income and pollution.

Finally, in upper-middle and high-income countries good governance is most productive is controlling pollution. Although most of these countries also score well on governance, yet there are exceptions. The countries that have gained the status of high-income countries in recent years because of the rental value of natural resources are not developed in true sense and there is scope for developing institutions. Investment in institutions in such countries is expected to yield maximum dividends for clean environment.

The study leads to a number of policy guidelines. Since dividends of good governance on the environment are negligible in poor countries, where environment is not prioritized in framing public policies. It is important to persuade these countries to reconsider their priorities with a long-term perspective. The persuasion can be in the form of aid packages for governance reforms that are made conditional upon the adoption and enforcement of specific environmental regulations. In middle income countries, the role of good governance in improving the environment is found to be more fruitful. In these countries, it is pertinent to weigh the costs and benefits of alternative strategies for addressing the issues of environmental degradation. These strategies include, in particular, investment in environment protection technology and investment in environment protection governance. Assessing the relative strengths of the two strategies would be useful for working out the optimal policy mix.

The present study provides the important insights into the relevance of governance in shaping the growth-pollution relationship. However, the study has certain limitations. The study combines four indicators of governance into one index, where the role of each indicator may not necessarily be the same. In addition, all 160 countries are combined in a single model, whereas the shape of EKC may differ between developed and developing countries. Future research may address along with these issues. With COVID-19 almost over, more usable data will hopefully be available to estimate the model using panel time-series econometric techniques.

Chapter 3

Evidence on the Shape of Environmental Kuznets Curve base on Quadratic Spline Function

Abstract

This chapter explores the shape of Environmental Kuznets Curve (EKC) on the basis of quadratic Spline function. Using panel data for 160 countries over the period 1996 to 2018, the study finds an N-shaped EKC over most of the observed range of per capita income. Furthermore, if very high per capita income range, experienced in few countries is also considered, the shape of EKC would extend the M-shaped. However, with expected technological advancements future studies are likely to find more conclusive evidence in favor of M-shaped curve with the second peak at an earlier per capita income. The study identifies sets of countries lying along various parts of EKC and recommends a flexible futuristic approach to setting of the environmental standards and regulations that can track various phases of structural transition in fast growing economies.

3.1 Introduction

The earth planet is currently passing through the catastrophe of covid-19 and undesirable changes in environment simultaneously. These problems have affected everyone without any distinction of country, religion, color, race, and political frontiers around the world. The polluted air and environment are the threat to both the poor as well as rich nations of the world. The emission from fossils oils, melting of glaciers, floods, global high temperature, droughts, polluted rivers and deforestation are confronted across the globe. However, an encouraging aspect of the situation is that both the poor and rich nations understand this threat and are working to reduce its impact on the current and future generations.

The apprehensions on environment due to excessive economic growth emerged in the 1960s in developed countries. These concerns were addressed in the UN1972 World Conference on Environment in Stockholm. In this conference the developing countries clearly addressed their priorities of economic growth rather than slowing down their development in the interest of environment.

The Environmental Kuznets Curve (EKC) postulates an inverted U-shaped relationship between per capita income and per capita pollution (Grossman & Krueger, 1991; Shafik and Bandyopadhyay ,1992; and Panayotou 1993). The changing relationship between economic growth and pllotion can be explained on the basis of following propositions. At initial phase of industrilzation, countries prefer to produce more goods and attain high standared of liviving while ignoring or undervluing environement concerns. As living standared improve with inreases in per capta incomes, the countries tend to pay more attention to environment compared to growth, so rate of inrease in environmental pollution slows down and ultimately environment tends to improve.

However, this is not the only type of relationship observed in empirical literature. A few studies for developing countries have observed positive relationship throughout the range of income (Ho, 2018; Sharma, 2011; Shafik, 1994; Holtz-Eakin & Selden, 1995), while CO_2 emission of some countries exhibits monotonically decreasing relationship with income (Baek, 2015;Oshin & Ogundipe, 2014; Shahbaz et al., 2017). Quite a few empirical studies for developed and transitional countries have observed inverted U-shaped relationship, which indicates that in these countries economic growth is sustainable and they are in the process of controlling their pollution emission (Holtz-Eakin & Selden, 1995; Agras & Chapman, 1999; Aldy, 2005; Ang, 2007; Yaguchi et al., 2007; Bölük & Mert, 2014; Bilgili et al., 2016). Another notable observation is the presence of N-shaped relationship, which indicates the reversal of the inverted U-shapes relationship once per capita income crossed another threshold level (Day & Grafton, 2003; Martınez-Zarzoso & Bengochea-Morancho, 2004;

Moomaw & Unruh, 1997; Hill & Magnani, 2002; Lee et al., 2009; Fosten et al., 2012; Álvarez-Herránz et al., 2017; Özokcu & Özdemir, 2017).

Given this background, one can argue that the standard functional forms like linear or quadratic functions are too restrictive to accommodate the underlying non-linearity in the relationship between per capita income and per capita pollution. The presence of N-shaped EKC indicates that the relationship of pollution with income may be represented by a cubic equation. It appears that empirical exploration of the shape of relationship between income and pollution is partially driven by functional form used in econometric analysis. For example, a quadratic equation cannot result in N-shaped relationship. By the same token a cubic equation cannot allow any more flexibility in the relationship beyond the N shape.

It is in this context that the study proposes an altogether different approach that does not confine the relationship between pollution and income to a rigid functional form. This approach is to fit a set of piece-wise regression equations across income ranges along with the imposition of smoothness restriction. We choose quadratic spline function with sufficient number of knots (shift points) with the sufficient parametric restrictions to ensure continuity and differentiability across the segmented regression equations.

3.2 literature review

The relationship between economic growth and pollutants has been tested for various countries by using different data sets and different functional forms. The findings are not restricted to the inverted U-shaped relationship between economic growth and environmental degradation proxies. After studying the literature, we come through different types of models, comprising inverted U-shaped, N-shaped, inverted N-shaped, monotonically increasing and M-shaped relationship for different countries at different levels of income and economic development (G. Yang et al., 2015). Here we present the relationship between different environmental pollution indicators and economic growth with respect to their shapes.

3.2.1. The inverted U-shaped relationship

The advent of inverted U-shaped empirical relationship of environmental pollutants with per capita income by Grossman and Krueger (1991a), Shafik and Bandyopadhyay (1992) and Panayotou (1993) has initated a new debate among the environmetal researchers. The literature of this type of relationship has become volumineous with varying results across countries and regions. The linterature also considers pollutants of various nature regardless of the laction and country. First Grossman & Krueger (1991a) studied the environmental consequences of North American Free Trade Agreement (NAFTA) by using three pollutants and economic growth. Their findings confirm that the suspended particulate matter (SPM) and Sulphur dioxide (SO2) becomes decreasing functions of the income after some turning point. This relationship was labelled as Environmental Kuznets Curve (EKC) in Panayotou (1993) because of the resemblance with Kuznets curve (Kuznets, 1955).

Selden and Song (1994) used SPM, SO_2, Nitrogen Oxides (NO_x) and carbon monoxide (CO) as environmental degradation factors and per capita income as explanatory variables for cross national panel. The study finds that all the four pollutants exhibit inverted U-shaped relationship with income. Aldy (2005) used the state level CO_2 emission for the period of 1960-1999 to study the production based and consumption based EKC for the USA. In both cases the inverted U-shaped relationship is confirmed, but turning point in the consumption based EKC is observed to be at higher income level than that in the production based EKC. Ang (2007) empirically studied the relationship between CO_2 emission, energy consumption and output for France over the period of 1960-2000. Findings of this study also verify the inverted U-shaped relationship between CO_2 emission and output.

Dutt (2009) extended the EKC relationship of CO_2 and income by incorporating governance, political institutions, socioeconomic conditions and the education policies in their model, which is analysed across 124 countries over the period of 1984-2002. The study varifies the existence of EKC relationships. A number of studies (Jalil & Mahmud, 2009; Lee et al., 2009; Tamazian et al., 2009; Musolesi et al., 2010; Bölük & Mert, 2014; Farhani & Shahbaz, 2014; Kasman & Duman, 2015; Nasreen et al., 2017; Gyamfi et al., 2021 Phong, 2019; Sharif et al., 2020) have confirmed the inverted U-shaped relationship between various pollutants and income for developed, transitional as well as developing economies for different time periods. These countries have commiited to curbing down the consumption of fossils in the icome growth process and high awareness leads to mitigation of pllution. Thus, the empirical outcome of EKC reveals that the economic growth and improvement in environment can co-exist if proper environmental policies are implemented.

3.2.2 U-Shaped and inverted N-shaped relationships

Despite the vast empirical evidence on the existence of EKC hypotheses across countries of the different income level, some studies have also found evidence contrary to the EKC hypothesis. These studies argue that the manufacturing, agriculture, FDI and trade of developing countries are based on fossils bases energy consumption, their CO_2 and other pollutant will tend to increase monotonically along the growth of income Ho (2018), Sharma (2011); Shafik (1994), Holtz-Eakin & Selden (1995) and.(Lau et al. (2014).

Kaufmann et al., (1998) estimated U-shaped relation between per capita GDP and atmosperic concentration of SO2 for the period between 1974 and 1989 for 23 including developed and developing countries. Alvarado et al., (2018) tested the empirical nexus between real per capita income and CO_2 emission for 151 countries for the time period of 1980 to 2016. The study verified a strong U-shaped link between real per capita income and carbon dioxide emission middle-high and low income countries. The U-shaped relationship between pollution and economic growth, propose that at initial phase with increase in economic development the level of environmental pollution fall, reaching to a threshold level then again tends to increase with the increase in economic development.

Lapinskienė et al.(2014) analyszed the relationship between GHG and gross domestic product of EU-27,Norway and Switzerland for the period of 1995-2010 by extended the EKC techniqes. The shape of EKC Patteren were differrent for differrent group of countries. At the start the GHG is decrasing with the increase in GDP until reaching a differrent turning points and then goes to increase with further gdp growth for Lithuania,Lativia,Estonia,Poland,and Bulgaria in the sample, which makes U-shaped relationship. Then the process of increasing GHG stops and the curve tends to move dowanward with further increase in gdp , which makes inverted N-shaped relationship between GDP and GHG. The relationship between GHG and GDP growth is negative for France, Denmark, Netherlands, Sweden, UK, and Germany. Whereas, the curve demonstrates inverted U-shaped relationship for Norway, Swetzerland , Irland, Greece, Spain, This differrent relationships and diffirrent threshold points needs to be further investigated.

López-Menéndez et al., (2014) extended the EKC model different functional forms and introduce renewable energy source for 27 European countries during the time 1996-2010 to explain the impact of GDP on the carbon dioxide emission. Their empirical results confirm N-shaped curve when the variables are used at level. The cubic terms become insignificant and the relationship become U-shaped by using logarithmic form of the model, only four out of twenty seven countries (Spain, Cyprus, Greece, and Slovakia) confirm inverted U-shaped pattern. The overall sample of European Union countries empirically exhibits inverted N-shaped curve. The high intensity of renewable energy source diminish the CO_2 generation, and supporting inverted U-shaped for group of countries with the use of high renewable energy intensity. Fakher et al., (2023), used Dynamic Seemingly Unrelated Regression Equations over the period 1994 to 2019 to study the impact of income on various environmental indicators for OPEC countries. The inverted N-shaped curve is verified for environmental performance and environmental sustainability with per capita income. The impacts of renewable energy were found positive on environmental quality while the impact of financial development, composite trade, and population density were deteriorating in this group of countries.

From the above studies, it can be noted that, the same period of analysis by changing the, group of countries, functional forms and methods of estimation the relationship exhibits different pattern of shapes between the pollutants and per capita income level. Although López-Menéndez et al., (2014) suggests that in the long run economic growth can affect CO_2

emissions inversely due to the use of renewable energy, energy efficiency and other environmentally friendly policies.

Musolesi et al. (2010) analyzed the relationship between CO_2 pollution and income over the period of 1959-2001 for 109 countries by classifying the countries in subsamples. By and large the industrial economies show EKC functional specifications. The European Union, Umbrella and OECD countries as well as overall full sample verify the EKC hypotheses (or inverted N-shaped relationship when estimated through cubic specifications). The 40 poorest countries and non-OECD countries demonstrates U-shaped relationship, which is in contrast to the EKC hypothesis relationship, indicating a monotonic increase in CO_2 after reaching its minimum threshold. Based on the heterogeneous samples, the findings advocate scale effect of GDP on CO_2 emission from each subgroup. Omisakin & Olusegun (2009) have also verified the presence of U-shaped relationship for Nigeria over the period 197-2005. Abdou and Atya (2013) and Saboori et al. (2012) have also confirmed the U-shaped relationship for Egypt and Indonesia respectively.

3.2.3 N-shaped and M-shaped relationships

Contrary to the earlier EKC literature researchers have also verified N- shaped relationship between income and CO_2 emission. Moomaw and Unruh (1997) assert that typically used reduced-form models do not deliver insights that could explain such shapes. The study observes N-shaped curve for 16 developed countries. This indicates that after reaching the minimum level, CO_2 again starts to increase with further growth in income. However, in the second phase only eight out of the 16 countries show significant negative relationships between income and pollution. Thus, the transition from positive to negative income elasticity of pollution is not robust. Lee et al. (2009) used Dynamic Panel model to investigate various relationship between per capita GDP and CO_2 emission. The estimated results support the inverted U-shaped and N-shaped relationship on global scale between per capita GDP and CO_2 emission.

Zanin & Marra (2012) observed that the relationship between income and pollution follows N-shaped pattern for Austria, inverted L-shaped pattern for Finland and Canada and M-shaped pattern for Denmark. shows M-shaped relationship between economic growth and CO2 emission. Here the M-shaped relationship between economic growth and CO_2 emission is thought as a special case EKC. Destek et al. (2020) also observed M-shaped curvilinear relationship between real income and carbon dioxide emission for the UK and Canada. The study further shows that N-shaped and inverted N-shaped shaped relationships between income and pollution hold for France and Germany respectively and inverted M-shaped (W-shaped) relationship holds for Italy, Japan and the USA.

In a similar study Yang et al. (2015) found four type of relationships between pollution and income including monotonic increasing, inverted U-shaped, M-shaped and inverted N-shaped relationships for different countries. The shape of relationship varies subject to changing regions and economic development. The developed counties exhibit M-shaped and inverted N-shaped curve whereas the developing and poor countries follow inverted N-shaped, inverted U-shaped and monotonically increasing relationships. Fakher et al., (2023), also revealed N-shape linkage of ecological footprints, adjusted net savings, pressure on nature, and environmental vulnerability to per capita income from 1994 to 2019 for OPEC countries.

Allard et al. (2018) used Quantile regression to assess the relationship of CO_2 emission with GDP per capita for 74 countries over the period of 1994-2012. They confirmed the evidence of N-shaped EKC for all income groups apart from the upper-middle-income countries.

From the discussion based on the previous studies empirical analysis of per capita economic growth and pollution emission relationship are not homogeneous and differences has been discovered on their shape across group of countries, income level and time period. Therefore, here we are going to introduce quadratic Spline function to study this association at different income level.

3.3 Methodology

The standard EKC is usually specified as a quadratic equation between log of per capita CO2 and per capita income. This function can yield no more than one threshold level of per capita income at which the relationship can change its direction from positive to negative or the other way round. However, there may be more than one such points where the nature of relationship may change due to different episodes of changes in preferences and technology. As a result, the relationship may turn out to be quite different from the shape postulated in the typical EKC.

To start with the proceedings, we here specify a quadratic equation in logs of per capita CO2 (*LCO2*) and per capita income (*LY*) as given below.

$$LCO2 = \alpha + \beta \, LY + \gamma \, LY^2 \qquad (1)$$

Parameters of the above relationship are now more flexible and allowed to change systematically across various threshold levels of per capita income. Let there be k such threshold levels denoted by LY_1, LY_2, …, LY_k and define the following shift dummies.

$$D_j = 1 \; if \; LY \; \geq LY_j \, , \quad = 0 \; otherwise \qquad (2)$$

Now we allow the three parameters appearing in equation (1) to vary systematically across the income thresholds in the following manner.

$$\alpha = \alpha_0 + \alpha_1 \, D_1 + \ldots\ldots + \alpha_k \, D_k \qquad (3a)$$

$$\beta = \beta_0 + \beta_1 D_1 + \ldots + \beta_k D_k \qquad (3b)$$

$$\gamma = \gamma_0 + \gamma_1 D_1 + \ldots + \gamma_k D_k \qquad (3c)$$

Substituting equations (3a) (3b) and (3c) into (1) and rearranging various terms, results in the following piece-wise regression equation.

$$LCO2 = \alpha_0 + \beta_0 LY + \gamma_0 LY^2 + (\alpha_1 + \beta_1 LY + \gamma_1 LY^2)D_1 + \ldots + (\alpha_k + \beta_k LY + \gamma_k LY^2)D_k \qquad (4)$$

The next step is to impose smoothness restrictions on this piece-wise equation. First impose the following condition to ensure the continuity of the relationship at the points of shift.

$$\underset{LY \to LY_j^-}{\text{Limit}} (LCO2) = \underset{LY \to LY_j^+}{\text{Limit}} (LCO2) \qquad (5)$$

These condition result in the following restrictions on the shift parameters.

$$\alpha_j = -\beta_j LY_j - \gamma_j LY_j^2 \qquad (6)$$

Substituting these conditions in the piece-wise equation (4) yields:

$$LCO2 = \alpha_0 + \beta_0 LY + \gamma_0 LY^2 + [\beta_1 (LY - LY_1) + \gamma_1 (LY^2 - LY_1^2)]D_1 + \ldots + [\beta_k (LY - LY_k) + \gamma_k (LY^2 - LY_k^2)]D_k \qquad (7)$$

The final step is to impose the following conditions on the above equation to ensure continuity of first derivatives of the function.

$$\underset{LY \to LY_j^-}{\text{Limit}} \frac{\partial CO2}{\partial LY} = \underset{LY \to LY_j^+}{\text{Limit}} \frac{\partial CO2}{\partial LY} \qquad (8)$$

The resulting restrictions on parameters are as follows.

$$\beta_j = -2 \gamma_j LY_j \qquad (9)$$

Substituting these restrictions in equation (7) yields the following final form of the function, which is a quadratic Spline function with k knots located at the points LY_1 to LY_k.

$$LCO2 = \alpha_0 + \beta_0 LY + \delta_0 LY^2 + \gamma_1 (LY - LY_1)^2 D_1 + \ldots + \gamma_m (LY - LY_m)^2 D_m \qquad (10)$$

We include five control variables in the relationship, which are governance index (*G*), share of geographical area under forestation (*Forest*), trade openness as measured by exports plus imports as ratio to GDP (*Trade*) and the shares of manufacturing and agricultural sectors in GDP (*Man* and *Agr* respectively). Also including random errors and the country plus period effects for panel data, the final estimable equation becomes:

$$LCO2_{it} = \alpha_0 + \beta_0 LY_{it} + \delta_0 LY_{it}^2 + \gamma_1 (LY_{it} - LY_1)^2 D_1 + \ldots + \gamma_m (LY_{it} - LY_m)^2 D_m + \theta_1 G_{it} + \theta_2 Forest_{it} + \theta_3 Trade_{it} + \theta_4 Man_{it} + \theta_5 Agr_{it} + \lambda_i + \phi_t + \varepsilon_{it} \qquad (11)$$

3.4 Data and Estimation Procedure

Data on governance indicators are available for the period 1996 onwards; therefore we select 1996 to 2018 as the period of analysis. The sample consists of 160 countries, which provides sufficient variation in all the variables of interest. Data on some variables are missing on a few data points which are filled by inter/extrapolation. The environmental pollution is approximated by per capita CO_2, while income variable is represented by per capita GDP. The data on CO_2 pollution are in million tons, which are converted to kilograms before expressing the variable in per capita terms. For valid international and over time comparison, the data on GDP are taken in constant PPP 2011 US dollars.

Governance index is computed using four governance indicators: Government Effectiveness, Regulatory Quality, Rule of Law; and Control of Corruption, which are constructed for the measurement of government's capacity to formulate and implement public policies and to ensure that their enforcement is respected by public and state organs. The last two indicators, Voice and Accountability and Political Stability and Absence of Violence are not included. The governance indicators are scaled -2. 5 to 2.5; where -2.5 and 2.5 indicate the worst and the best possible states of governance. Since all the four indicators are highly correlated, they are converted to a single index using Principal Component Analysis (PCA). The governance index so obtained is scaled linearly from zero to one.

Data on CO_2 emission are taken from *Global Carbon Project*, while the data on the governance indicators are collected from *Worldwide Governance Indicators* (*WGI*). The data on all the remaining variables including GDP, population, forest area as a proportion to total area, trade openness (exports plus imports divided by GDP) and the shares of agricultural and industrial sectors in GDP are taken from *World Development Indicators* (*WDI*).

It appears from the details presented in methodology that flexibility in the relationship between per capita income and per capita CO_2 is achieved through the introduction of knots or threshold levels of per capita income. The number and locations of these knots must be selected before final estimation of the spline function. There are two approaches to make this selection. The first approach is to follow a systematic procedure on the basis of some criterion function like likelihood. This is a lengthy procedure in which knots are introduced one by one (sequentially) and their location is determined using grid-search process. Although this approach would yield relatively efficient number of knots and their location, it could be too time consuming and may not necessarily have substantial advantage.

Table 3. 1: Results of Tests for Model Selection

Test Type	P-Value of Test Statistic	Conclusion
LM Test: Breusch-Pagan Honda King-Wu Standardized Honda Standardized King-Wu	 0.000 0.000 0.000 0.000 0.000	 Country random effects are <u>not equal to zero.</u>
LM Test: Breusch-Pagan Honda King-Wu Standardized Honda Standardized King-Wu	 0.000 0.000 0.000 0.000 0.000	 Period random effects are <u>not equal to zero.</u>
Wald Test: F-statistic Chi-square statistic	 0.000 0.000	 Country fixed effects are <u>not equal to zero.</u>
Wald Test: F-statistic Wald Chi-square statistic	 0.163 0.121	 Period fixed effects are <u>equal to zero.</u>
Hausman-Wu Chi-square Test	0.000	Random effects are <u>correlated</u> with explanatory variables.
Hausman-Wu Chi-square Test	0.000	Random effects are <u>correlated</u> with explanatory variables.
Overall Conclusion	Country Fixed Effects model appears most appropriate.	

The alternative approach is to introduce sufficiently large number of knots located with small intervals. In the present context this approach seems acceptable because the objective here is to introduce further flexibility in the relationship over and above what a quadratic relationship would yield and for this purpose exact knowledge about the locations of knots is not crucial. Since the variable under consideration, that is per capita income, has right-skewed distribution, we place the knots on intervals in logarithmic scale. The data on log per capita income is spread over the range 6.13 to 11.77 with small number of observations in the upper tail. So, we set ten knots at the points: 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0, 10.5 and 11.0.

The possible presence of fixed and random effects in equation (8) is tested using Wald and Lagrange Multiplier (LM) tests respectively are shown in Table 1. In case the presence of both cannot be rejected, the choice between the two types of effects can be made on the basis of Housman and Wu test. Preliminary estimation shows that apart from being affected by income and other control variables, CO_2 pollution also tracks its past time path. Therefore, the model has a dynamic structure and in the presence of country random effects or first order autocorrelation in errors, usual estimation by fixed or random effects models would yield biased estimation due to the resulting endogeneity of lagged dependent variable. In this case the Generalized Method of Moments (GMM) is generally regarded as a preferred estimation technique.

Thus, the spline function is estimated by GMM using the instrumental variables recommended by Arellano and Bond (1991), which are based on the condition that in each period lagged dependent variable with two or higher period lags is orthogonal to random errors. The choice of lag 2 assumes that the error term in first difference form has non-zero autocorrelation at first lag but zero autocorrelation at higher lags, which means that the original random error (without the first difference) has zero autocorrelation at any lag. Additional instruments can also be made available by using similar dynamic structure or simple static structure on the moment conditions on the other variables appearing on right-hand side of the equation.

3.5 Results

PCA of governance indicators shows that the first Principal Component accounts for 94.35% of the variation in the governance indicators. Therefore, we have constructed a single governance index scaled from zero to one. Equation (11) is initially estimated by various techniques including Pooled Least Squares, Fixed Effects model and Random Effects model. Thereafter appropriate tests are applied to choose between the alternative models. Table 1 summarizes the results of these tests. The first two rows of the table after the heading row show results of LM test to choose between Pooled Least Squares and Random Effects models. Various tests statistics turn out to be highly significant, resulting in rejection of the null hypotheses that country or period random effects are equal to zero. Therefore, Pooled Least Squares model is rejected in favor of two-way Random Effects model.

The next two rows show the results of Wald test to choose between Pooled Least Squares and Fixed Effects models. The results show that while the null hypothesis that country fixed effects are equal to zero is rejected, the null hypothesis that period fixed effects are equal to zero cannot be rejected. Thus, Pooled Least Squares and two-way Fixed Effects models are rejected in favor of country Fixed Effects model. Finally, the last two rows present the results of Housman-Wu test and the result show that the country and period Random Effects models are rejected because both the categories of random effects are significantly correlated with explanatory variables.

The above results lead to the overall conclusion that country Fixed Effects model is preferably over the other models considered so for. However, the estimated model shows presence of significant autocorrelation in errors that render the parameter estimates biased. To tackle this problem and to allow for the possibility that country effects may have some random components, the model is converted to first difference form to drop out the country effects and the resulting model is estimated by Generalized Method of Moments (GMM). The instrumental variables include two period lags of dependent variable with orthogonality conditions applied period by period as proposed by Arellano and Bond's (1991) instruments. In addition, two-period lags of all the other variables appearing on right-hand side of the equation are also used as instruments with orthogonality condition applied to the entire sample (rather than period by period).[2]

Parameter estimates of the spline function are presented in Table 2. The signs of various parameters are as per our expectations. The coefficient of log per capita income is positive, while the coefficient of the square of log per capita income is negative and both the coefficients are statistically significant at one percent level of significant. However, the presence of additional variables involving income indicates that the relationship may not exactly follow the inverted U-shaped pattern. In particular, the results show that nine out of the ten shift variables involving per capita income are highly significant, while one of them representing income threshold at log per capita income equal to 9.0 is quite insignificant and, hence, dropped. The nature of this relationship will be presented in a graph shortly. But before that we want to complete our discussion on the other variables present in the model.

The governance index shows negative and significant relationship with CO_2 pollution. This result is according to expectation because the presence of strong and effective institutions would generally ensure enactment, enforcement, compliance, and respect of such regulations that are needed for environmental protection.

[2] The orthogonality conditions on the variables other than lagged dependent variable are not applied period by period to avoid over-congestion of instruments and the resulting loss of efficiency.

According to the parameter estimate, each one percentage point improvement in governance index is on average associated with 0.135 percent reduction in CO_2 pollution.

Table 3. 2: Spline Function Estimated by on GMM (Dependent variable is log per capita CO_2)

Variable	Coefficient	t-Statistic
Log per capita GDP: LY	251.60	7.02*
Log per capita GDP: LY^2	-19.257	-6.95*
Governance index (G)	-0.135	-3.02*
$(LY_{it} - LY_1)^2 D_1$	15.848	5.29*
$(LY_{it} - LY_2)^2 D_2$	8.319	11.80*
$(LY_{it} - LY_3)^2 D_3$	-6.221	-13.42*
$(LY_{it} - LY_4)^2 D_4$	1.320	3.47*
$(LY_{it} - LY_5)^2 D_5$	-1.180	-6.21*
$(LY_{it} - LY_7)^2 D_7$	1.261	4.96*
$(LY_{it} - LY_8)^2 D_8$	-2.165	-4.23*
$(LY_{it} - LY_9)^2 D_9$	7.656	9.52*
$(LY_{it} - LY_{10})^2 D_{10}$	-8.552	-10.84*
Forest	-0.821	-2.01**
Man	-0.663	-5.26*
Agr	-1.717	-20.80*
One-year lagged dependent variable	0.229	19.75*
J-statistic	148.30	0.39
Note: The statistics significant at 1%, 5% and 10% levels are indicated by *, ** and *** respectively.		

The proportion of geographical area covered under forests also has a negative effect on pollution. It is a well-known observation that the presence of forests is a great source of environmental protection because on net basis trees absorb carbon dioxide from atmosphere. The results show that each one percentage point increase in forest area can be associated with 0.821 percent reduction in the per capita CO_2 emission.

The last two variables are the shares of manufacturing and agricultural sectors, whereas the share of services sectors is used as the base variable for comparison. The results indicate that compared to the services sector, both the manufacturing and agricultural sectors tend to produce less CO_2 pollution. While the negative association of agricultural sector with pollution is an expected result, the negative association of manufacturing sector with pollution is surprising because manufacturing processes involves intensive use of energy. One possible explanation is that in middle to high income countries, especially the developed countries pollution control regulations on manufacturing industries are quite strict and despite intensive use of energy, pollution is better managed than in the uncontrolled industries.

Using the parameter estimates presented in Table 2, we now show graphically the relationship between per capita income and per capita CO_2 pollution. While tracing the relationship the values of all the variables other than per capita income and per capita CO_2 pollution are set equal to the respective sample means. Figure 1 draws the resulting spline function. The figure shows that there are three distinct threshold levels of annual per capita income at about \$9160, \$46960, and \$94470 where the direction of relationship between of per capita income and per capita CO_2 pollution changes from positive to negative or the other way round. In particular, the curve peaks first at annual per capita income of \$9160 and then at \$94470, which is more than 10 times the income at the first peak.

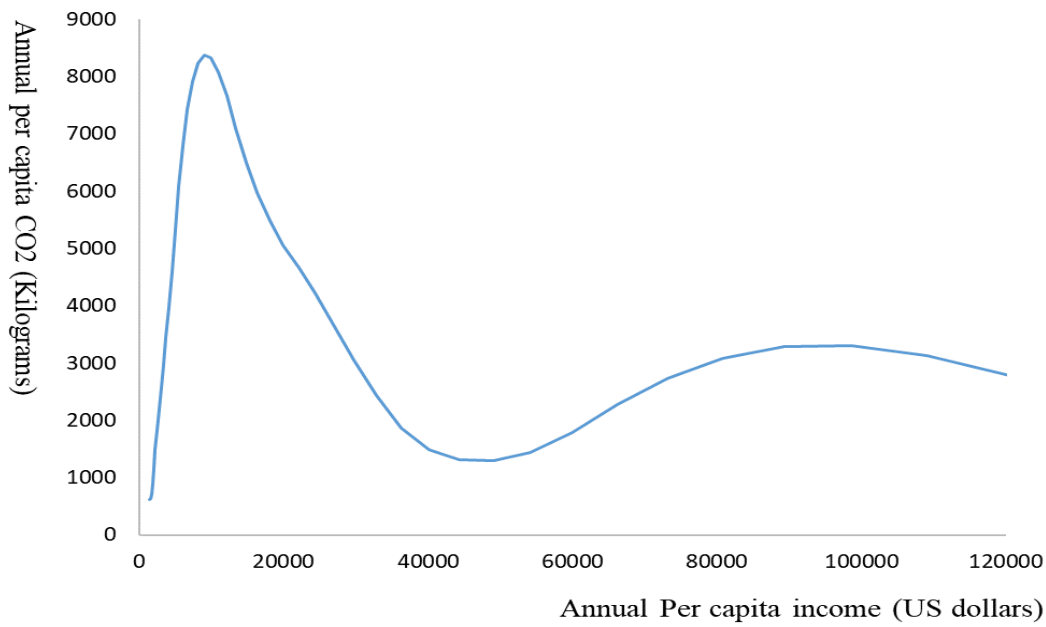

Figure 3. 1: Relationship between Per Capita CO_2 and Per Capita Income

To understand this pattern, let us first note that most of the countries where per capita incomes are below the first threshold are in Africa, Asia, Latin (South) America and some in East Europe. Some of the large and prominent countries in this category include Bangladesh, Congo, India, Nigeria, Pakistan, Philippines, and Vietnam. Economic growth in these countries has resulted in the emergence of the middle class and rising standards of living. This transition has accompanied with rising demand for energy intensive appliances and products like motor vehicles, air conditioners, vacuum cleaners, washing machines, dish washers, and other kitchen appliances. The rising share of energy in income means increase in pollution. This increase in pollution is further fueled by technological advancement in the form of mechanization of production processes whereby human labor is substituted by energy intensive capital input. Energy-intensive and, hence, pollution-intensive goods enter the way of life as luxury goods through direct consumption or through energy-intensive production processes. This process continues till the first threshold level of income, that is $9160 per annum.

However, when per capita income increases beyond this threshold ($9160), the direction of relationship turns negative. Some of the large countries that lie on this declining portion or have recently crosses the threshold level include most of the European countries, Brazil, Canada, China, Colombia, Egypt, Indonesia, Japan, Mexico, Russia, South Africa, South Korea, and Turkey. The negative relationship between per capita income and pollution in such countries indicates that when incomes exceed certain level, quality gets precedence over quantity in the average consumption basket. Emphasis shifts from goods to services that include healthcare, recreation, and clean environment. At higher levels of per capita income, the countries are also in a better position to spend economic resources on cleaning of environment by adopting energy efficient technology and consumption baskets.

The above inverse relationship between income and pollution continues, but become weaker as per capita income grows further. When per capita income crosses the threshold level of $46960, the relationship again turns positive. As a result some of the gains in environmental quality is offset as higher per capita income enable households to afford consumption of energy-intensive products. Large luxury motor vehicles replace the small energy-efficient vehicles and travel-intensive leisure activities increase. Households can afford heating and cooling systems for the entire house rather than one or two rooms. Some of the countries that fall in this category include Denmark, Hong Kong, Norway, Singapore, Switzerland, The Netherlands, The United States of America, and some of the oil-rich Middle Eastern countries. Although, the positive relationship between per capita income and CO_2 emission indicates negative relationship between per capita income and environmental quality, it does not necessarily means that environmental quality is considered as inferior good. Rather compromise on environmental quality is the cost of raising living slandered that the society is willing to bear in terms of negative externality.

The above pattern is expected to continue till very high per capita income of \$94470. At this threshold, another peak in the EKC occurs after which per capita CO_2 pollution again starts declining along with increase in per capita income. While Qatar is the only country where per capita income has exceeded this threshold for the entire period of analysis (ranging from \$105411 to \$129349), three other countries have also touched this level of income. These are Kuwait (for two years 2006 and 2007), Luxembourg (for four years 2007 and 2008, 2016 and 2018), and United Arab Emirates (for nine years 1996 to 2004). This implies that for all practical purposes we can say that this declining portion of EKC is not widely observed; it is only a theoretically predicted behavior which indicates that when world's rich economies grow to achieve very high per capita income levels, technological advancement would make it possible to maintain luxurious living standards even with low energy intensity and with better ways to manage pollution emission.

We can conclude that for the entire range of per capita income currently prevailing in the world, EKC follows an M-shaped path, indicating the presence of two peaks in the relationship at a huge gap of income. However, this observation is based on past data. Since technology is changing at a fat pace, we expect that the future empirical studies involving more recent data will incorporate the impact further technological advancements and as a result the second peak in the relationship between environment and income may be observed at a lower per capita income and the data may provide wider support and recognition to M-shaped EKC.

If we ignore the right-tail ending portion of EKC, which finds little empirical prevalence, it would be safe to conclude that EKC follows an N-shaped pattern for most of the observed range of per capita income prevalent in the world. This shape has also been observed in some other studies like Lee et al. (2009), Zanin and Marra (2012), Yang et al. (2015) and Destek et al. (2020).

However, there is one crucial difference between findings of the existing literature and the results obtained in the present study. The N-shaped relationship between income and pollution found in the existing literature is categorical, which predicts a pessimistic future scenario of environment unless economic growth is halted. On the other hand, the present study suggests that the positive relationship between income and pollution in the high per capita income range is ultimately expected to be reversed if the process of economic growth and technological advancement continues.

The existing literature on growth and carbon emission is not confined to a single model or shape but proposes various ways to explore it. In this paper we used quadratic Spline Functions which is a novel approach to explore the N-shaped and including proposed M-shaped relationship at very high-income level between economic growth and carbon dioxide emission of a panel of 160 countries. Moreover, the inverted U-shaped curve relationship (EKC) studied in the previous research could be verified in this paper before the second turning point (N-shaped) automatically. In contrast to the previous studies and estimation methods none of them clearly depicted N-shaped EKC significantly.

3.5 Conclusion

Using panel data for 160 countries for the period 1996 to 2018, this study estimates a quadratic spline function allowing smooth changes in level and slope at nine different thresholds of income. The study finds that for most of the empirically observed per capita income range, EKC follows an N-shaped profile. However, based on statistical analysis the study predicts that when per capita incomes in rich countries grow to a very high level, which is currently observed in few countries only, another peak in the relationship would occur, thereby extending the N-shaped curve to the M-shaped one.

Matching various ranges of estimated EKC with the observed per capita incomes in various countries in recent years, the study identified three broad categories of countries. The first category mostly includes poor and middle-income countries in Africa, Asia, Latin (South) America and some in East Europe where per capita incomes are relatively low, and state of governance is also not impressive. In this set of countries that also includes the largely populated emerging economies like Bangladesh, Congo, India, Nigeria, Pakistan, Philippines, and Vietnam, economic growth in near future is expected to result in growing consumption of energy-intensive products with little inclination to adopt such technologies that could mitigate the adverse environmental consequences of economic growth. This is expected to result in increased pollution in the coming years.

The second category of countries consists of upper-middle to high income countries where per capita incomes are reasonably high and governance indicators are good. This category consists of developed countries in Europe, Brazil, Canada, China, Colombia, Egypt, Indonesia, Japan, Mexico, Russia, South Africa, South Korea, and Turkey. Most of such countries have gone past the early phase of economic development and their typical households consider clean environment an important component of consumption basket. High per capita incomes also make it possible to invest in environment protection and Research and Development activities oriented towards a cleaner environment.

The third category of countries includes rich countries like Denmark, Hong Kong, Norway, Singapore, Switzerland, The Netherlands, The United States of America, and some of the oil-rich Middle Eastern countries. Households in these countries can afford luxurious consumption baskets that include luxury cars, vast travels, and heating-cooling systems for entire homes and so on. Due to energy-intensive living, increase in income levels in that upper range is expected to raise environmental pollution.

The study also predicts that when richest economies of the world grow further, technological advancement would possibly make it possible to maintain luxurious standards of living without consuming too much energy but with better management of environmental issues.

Main conclusion of the study is that the relationship between income and pollution is not simple, and its nature varies fundamentally across different ranges of per capita incomes. Therefore, a uniform set of environmental regulations and their enforcement would neither be desirable, nor effective. World Environment Organization and other such entities could come up with different sets of environmental standards and policy prescriptions for the countries at different stages of development. In this context a flexible futuristic approach that can track various phases of structural transition in fast growing economies would be desirable.

*Chapter 4

Does Pollution Haven Hypothesis Hold: The Role of Foreign Versus Domestically Owned Capital in CO_2 Emission

Abstract

This chapter investigates the Pollution Haven Hypotheses (PHH) by using EKC functional framework. A panel of 157 countries over the period 1990 to 2018 is selected based on the availability of data. In this novel study on the investigation of PHH, we replace the commonly used variable FDI by the stock of foreign owned capital, estimated from the flow of FDI using perpetual inventory method. Estimating domestic owned capital in the same manner, we construct the data series on foreign to domestic owned capital ratio. This ratio is then used as a moderating variable in the standard EKC equation. The results show that PHH stands rejected. Rather, the presence of foreign-owned capital is found to be a contributing factor in reducing CO_2 pollution though the magnitude this reduction is moderate at best.

*A portion related to this work is also published and can be found as following:

Hussain, I., Ahmad, S., & Ahmad, E. (2022). Investigating the Pollution Heaven Hypothesis and Environmental Kuznets Curve: Evidence from Panel ARDL Approach, Journal of Finance & Economics Research, 7 (2), 1-17.

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4.1 Introduction

The growing concern about the environmental degradation experienced during the past few decades has attracted the attention of researchers, policy makers and non-governmental organizations (NGOs) around the globe. Environmental degradation is taking place due to the release of physical and chemical substances into the atmosphere, water, and soils. Consequently, their concentration in the environment adversely affects animals, plants, and other species of life. The recent Intergovernmental Panel on Climate Change (IPCC) has warned that the global rising temperature up to 3C is due to the excessive release of Green House Gases (GHG) and other chemical intoxicants, which have become the source of the climate change (Pielke Jr et al., 2022).

Alongside the rising pollution, global interdependence of the world economies has boosted the wave of foreign direct investment (FDI) movement across countries. FDI plays the role of an engine in economic development, through the transfer of technological innovation, labor mobilization, and skills transfer in the recipient countries (Appiah-Otoo et al., 2023 andVelde, 2006).

However, along with its positive impacts on economies of the host countries, its negative spill-over effects in the form of pollution in the host countries has created a hot debate amongst researchers. It is widely believed that many important greenhouse gases are relocated from the FDI exporting countries to the FDI recipient countries. It is claimed that tight environmental regulations, public awareness and high input prices the polluting activities in developed countries have higher opportunity costs compared to the developing countries. The lower wages of labour and, lose environmental regulations entice the firms and companies to transfer their production activities to the developing countries. As a result, in FDI hosting countries the production of goods and services are accelerated along with the emission of pollution. Thus, when a country imports energy-intensive goods and exports service-based goods, it practically outsources its pollution. This transfer of pollution-intensive investment to the host countries is known as Pollution Haven Hypotheses (PHH).

The PHH mainly addresses the transfer of FDI across countries in three dimensions: relocation of pollution-intensive manufacturing industries to the low income countries, displacement of the production of dangerous discharge in the manufacturing process, and the exploitation of non-renewable natural resources of the host countries, which have everlasting impact on the sustainable development programs of the developed countries (Zomorrodi and Zhou, 2016).

On the other hand, with the transfer of investment from developed to developing countries Pollution Halo Effects are claimed, which refer to the proposition that with the transfer of FDI advanced technology flow and optimal use of resources have favorable impacts on the pollution (Chichilnisky, 1994; Mani & Wheeler, 1998; Millimet and Roy, 2016; Wang and Luo, 2022).

The existing literature on PHH is based on the relationship of pollution with FDI. However, since FDI is flow during a unit of time like a year, its relationship with pollution ignores the impact of already existing stock of capital accumulated through the past FDI flows. This omission results in misspecification and possibly misleading results. For example, if the relationship of pollution with FDI is positive, it would mean that a decrease in FDI should reduce the pollution level. However, any positive flow of FDI, even when it declines, adds to the stock of capital unless the FDI magnitude falls short of depreciation of the stock and, as a result, contributes to more pollution.

In the light of above observations, the present study asserts that the practice of using FDI flow as the focused variable in the research on PHH is flawed and proposes that the variable FDI should be replaced by the appropriately construction stock variable. It is argued that what matters in the context of PHH is the composition of the host country's capital stock rather than investment flows. This simple argument rests on the theory of production according to which the level of output flow in a period depends on that existing stock of capital along with the other variables.

Thus, the objective of this study is to reconsider and empirically investigate the position of PHH by shifting the focus of analysis from FDI flow to the stock of accumulated FDIs, referred in this paper to as foreign owned capital stock. The analysis is conducted in the framework of Environmental Kuznets Curve (EKC). The standard EKC equation is extended to include the composition of capital stock with respect to foreign and domestic ownership as a moderating variable. In this way the key parameters of the EKC are allowed to respond to changes in the composition of capital stock. In this way the position, slope and curvature of EKC can change when the composition capital stock between foreign and domestic components is altered.

The study employs panel data of 157 countries over the period 1990 to 2018. Pollution is represented by CO_2 emission, a widely used indicator of environmental degradation on which data are easily available. Economic activity is measured by GDP. The foreign and domestic capital stock series are generated from the corresponding series of investment flows using perpetual inventory method with the assumption of standard 5% depreciation rate. Then the ratio of foreign to domestic capital stocks is used as a moderating viable in interactive form with the three parameters of EKS. Apart from the main EKC variables (CO_2 and GDP) a set of control variables are used that comprise the proportion of geographic area covered under forests, trade openness (total foreign trade to GDP ratio), and the shares of manufacturing and agriculture outputs in GDP.

The rest of the study consists of five sections that are literature review, methodology, data, result and conclusion.

4.2 Literature Review

The rapid liberalization of trade and transfer of manufacturing industries to developing economies has created an academic debate amongst researchers about their impact on environmental pollution. The studies on the impact of foreign capital transfer on environmental degradation remained debatable from the very beginning across the world on account of contradictory empirical findings. Here in this section, we will present a review of studies on the impact of FDI on the CO_2 emission of various groups of countries.

The debate was initialted by Copeland and Taylor (1994) who considered the implications of trade between North and South for the World's pollution level. The study developed a theoretical model and showed that "income gains arising from an opportunity to trade can affect pollution in a different way than income gains obtained through economic growth and, moreover, that economic growth has different effects on pollution in a free trade regime than in autarky. If environmental policy is set optimally, then potential increases in pollution generated by economic growth in autarky can be prevented by a policy-induced switch to cleaner methods of production. … However, international trade opens up a different channel that may nevertheless lead to an increase in world pollution."

The essence of PHH in Copeland and Taylor (1994) was that free trade can lead to higher pollution levels because economic forces lead to North-South trade in which the developed North specializes in more environment-clean prodcuts while the developing South specializes in pollution-intensive products. In this way the less developed countries become haven for the pollution and the waste dumps for the developed countries (Kellenberg, 2010; Yang et al., 2018; Michida and Nishikimi, 2007; Chichilnisky, 1994; Mani and Wheeler, 1998; Millimet and Roy, 2016; Wang and Luo, 2022).

Grossman and Krueger (1995) also discovered that as the country gains some upturn in income due to economic growth, they give off the production of energy and pollution intensive goods and imports them from those countries which have less restricted environmental regulations. So, the developed countries displace their pollution to developing countries.

Chichilnisky (1994) and Sapkota & Bastola (2017) observed that the lack of infrastructure and skilled labour leads the low-income countries to compromise on environmental regulation to attract FDI and transfer dirty industries from developing countries.

The rebutlal of PHH came in the form of Pollution Halo Hypothesis acccording to which when developed countries shift energy-intensive activities to developing countries through FDI, they are cary advanced technologies along FDI, thereby helping reduce pollution per unit of output in developed countries (Mani & Wheeler, 1998; Millimet and Roy, 2016; Millimet and Roy, 2016; and Wang and Luo, 2022). It is argued that technology transfer by means of FDI inflows enables developing countries to substitute ecologically friendly techniques in place of old pollution-causing techniques. This in turn optimizes the inputs consumption and less pollution will be contributed.

Dinda (2004) rejected PHH on the grounds that the polluting industries that incline to locate to developing countries would also surge the earnings of the recipient countries. Consequently, the host countries would initiate strict environmental protection laws. Therefore, over the time replacement of polluting industries from the countries with stringent environmental regulations would be discouraged because all countries would face the same level of strict regulations. Haisheng et al. (2005) also rejected PHH and argued that trade and FDI have no negative impact on the environment because the positive impacts of FDI on economic growth are helpful in developing new technologies to decrease pollution emission.

Thus, it became debatable whether transferring energy intensive products to developing countries through FDI causes more or less pollution in the FDI recipient countries. However, Lucas et al. (1992) affirmed even before this debate that strong environmental regulations in developed countries have displaced the pollution generating industries to the lower develop countries, and imports these goods from these countries. These, high energy intensive, pollution embodied imports lead the exporting countries to manufacture more and so the pollution increases in developing countries. Later on, carrying the same line, Lee (2013) argued that developing and emerging economies compete with one another for attracting prospective investments that provide direct funding of foreign capital to speed up economic growth through technology diffusion, and productivity enhancements.

A pile of quantitative studies on the validity of PHH examining the impact of FDI on the environmetal pollution in host countries has accumulated over the past 30 years. But there is no consensus among the researchers for validity of the hypotheses. Here we are going to discuss different studies in detail for different regions and groups and time period, with models to explore the existing picture of the literature.

Table 4.1 presents the summary of various empirical studies. The table shows that the literature collects evidence in favor of PHH or against PHH from five different categories of countries, which are not necessarily mutually exclusive. The opposite stance of PHH is defined pollution halo effect and termed as PHL in our literature table. This means that multinational companies transfer their energy efficient and green technologies to the host countries, as a consequence pollution rate decreases. These categories are the countries representing a) the world; b) a particular region of the world (e.g. a continent); c) specific economic characteristics like the level of development; d) recipients of large FDI volumes; e) recipients of FDI from specific types of countries; and f) individual countries.

Table 4. 1 : Summary of Empirical Work on Pollution Haven Hypothesis

Study	Countries/Region	Results
Adeel-Farooq et al., (2021)	76 developed and developing countries	• PHH suppported for FDI from developing to low and lower-middle income countries • PHL supported for FDI from developed countries to developing countries
Muhammad et al. (2011)	110 developed and developing countries	• PHH supported • Slack environmental regulations, unattracted infrastructure and unskilled labors were the main causes for developing countries to compromise on protection of environment.
Shao (2017)	188 countries	• PHL supported for worldwide sample, middle and low-income countries and high-income countries.
Bouzahzah, (2022)	40 African countries	• Inconclusive for the short or long run
Gharnit et al. (2020)	14 African countries	• PHH Supported
Gyamfi et al. (2021)	Sub-Saharan Africa: 14 oil producing and 27 non-oil producing countries	• PHH Supported overwhelmingly
Kivyiro and Arminen (2014)	Six Sub-Saharan African Countries	• PHH Supported for Kenya and Zimbabwe • PHL supported for South Africa and Democratic Republic of Congo • The different results are attributed to diverse bases of economic structures of the countries.
Ahmed et al., (2022)	55 Asia-Pacific countries	• PHH Supported
Ansari et al. (2019)	Five Asian regions covering 29 countries	• PHH Supported for the entire sample, East Asia and South Asia • PHL supported for Southeast Asia • Inconclusive evidence for West Asia and Central Asia
Nawaz et al. (2021)	Four South Asian countries: Bangladesh India, Pakistan, Sri Lanka	• PHH Supported
Zhu et al. (2016)	Five Asian countries: Indonesia, Malaysia, Philippines, Singapore, Thailand	• PHH supported • The relationship between FDI and pollution varies across pollution quantiles
Javorcik and Wei (2003)	25 East European economies including the former USSR region	• PHH rejected • No indication that dirtier manufacturing is migrating to the countries for the reason of their easier environmental regulations.
Al-Mulali and Tang (2013)	Gulf Cooperation Council countries with well-built infrastructure	• PHL supported • FDI is the main diver in getting energy efficient technologies to the recipient countries
Destek and Okumus	Newly industrialized countries	• PHL supported(Destek & Okumus, 2019)(Destek & Okumus, 2019)(Destek &

(2019)		Okumus, 2019)(Destek & Okumus, 2019)
Mert and Bölük (2016)	21 industrialized countries	• PHL supported • Increase in FDI leads to reduce environmental pollution more than percentage increase in FDI.
Apergis et al. (2022)	BRICS (FDI from OECD)	• PHH supported for FDI from the UK and Denmark • PHL supported for FDI from France, Germany and Italy • Both PHH and PHL rejected for FDI from Japan, Austria, Finland, Portugal, Netherland and Switzerland
Balsalobre-Lorente et al. (2022)	BRICS	• PHH Supported
Banerjee and Murshed (2020)	BRICS and G7	• PHH supported for BRICS • PHH rejected for G7 • BRICS countries are labelled pollution haven for foreign investers.
Yilanci et al., (2020)	BRICS	• PHH Supported in the overall sample • Mixed evidence for individual contries
Shao et al. (2019)	BRICS and MINT (Mexico, Indonesia, Nigeria, Turkiye)	• PHL supported
Pao and Tsai (2011)	BRIC (excluding South Africa)	• PHH Supported
Birdsall and Wheeler (1993)	Brazil, China, Mexico	• PHL supported
Hussain et al., (2022)	Brazil, Canada, China, France, Germany, India	• PHL supported
Wheeler (2001)	Brazil, China, Mexico	• PHL supported
Akram et al. (2022)	China	• PHH supported
Honglei et al. (2011)	China's 30 regions	• PHH rejected
Lan et al. (2012)	China	• PHH not supported
Ren et al. (2014)	China	• PHH supported
Wu et al. (2022)	China	• PHH rejected
Zhang and Zhou (2016)	China's 30 regions	• PHH rejected • Cheap workers and strong economy of China, rather than slack environmental protection laws, have attracted FDI. • The regions with strong environmental regulations also attracted a considerable amount of FDI in their industries.
Baek and Koo (2017)	China, India	• PHH supported for China • PHH weakly suported in long run and strongly supported in short run for India

		• Pollution caused by FDI in India is dangerously high. • PHH holds in both the countries because of lenient environmental regulations that attract heavy investment in the industrial sector.
Rana and Sharma (2019)	India	• PHH supported
Chandrika et al. (2022)	India	• PHH supported
Ur Rahman et al. (2019)	Pakistan	• PHH supported
Polloni-Silva et al. (2021)	592 Brazilian municipalities	• PHL supported
Kim and Seok (2022)	South Korea	• PHH supported
Cil (2022)	Turkey	• PHH supported
Seker et al. (2015)	Turkey	• PHH supported

A number of interesting results are notable from the table. First, the evidence in favor of PHH is heavier than the evidence against it or the evidence in favour of the opposite hypothesis, that is PHL. Second, whether or not the PHH holds depends on the level of development of the FDI recipient countries. For example, most of the studies on Africa show that PHH holds in, while only one study supports PHL Likewise, most of the studies for Asia support PHH. However, the hypothesis does not find support from West and Central Asia, the relatively more developed regions of Asia. The evidence from the Gulf Cooperation countries, where infrastructure is well built, also shows that these countries have reduced pollution by importing clean technology through FDI. Thus, even within Asia, the relatively developed regions do not support the validity of PHH.

The evidence from industrialized countries including G7 as well as the newly industrialized countries is in sharp contrast to PHH. In these types of countries, it is the PHL that holds or at best both the PHH and PHL are rejected.

It is further observed that the evidence from the major recipients of FDI, BRICS countries, mostly supports PHH. Since BRICS countries receive a major portion of global FDI flows, the support of FDI from these countries is carries extra weight to conclude that FDI is an indirect channel of exporting pollution to the developing countries of the world.

For the individual counties the evidence is mixed. For example, China and India are the two major recipients of FDI and China is far more developed than India. The table shows that most of the studies for China do not support PHH, while most of the studies for India support PHH. The literature also points out that the presence of effective environmental regulations is important to control the environmental cost associated with FDI.

We can conclude the literature review by the observation that PHH is generally supported, especially for the poor and developing countries, while the evidence against PHH is also reasonably strong. Thus, given the current state of knowledge, it is difficult to decide conclusively whether the recipients of FDI pay extraordinary environmental cost.

4.3 The Model

As mentioned in the introduction, the main contribution of this study is to recognize the role of capital stock owned by foreign investors rather than the flow of investment in the context of PHH. Foreign owned capital stock is assigned the role of a moderator in the relationship between output and pollution as represented by the standard EKC modelled. Thus, we start with the EKC equation in which CO_2 is the per capita emission of CO_2 and y is per capita GDP:

$$\ln CO2 = \alpha + \beta \ln Y + \gamma\,(\ln Y)^2 + U \qquad (4.1)$$

The three parameters present in this equation determine the position, slope, curvature and turning point of EKC curve. To bring-in the impact of foreign capital, these parameters are allowed to vary in response to changes in the composition of capital stock between foreign and domestic owned capital. We represent the composition of capital stock by the ratio of foreign to domestic capital stock, denoted by k. The sensitivity of parameters of the EKC to the composition of capital stock is represented by the following equations.

$$\alpha = \alpha_0 + \alpha_1 \log k \qquad (4.2a)$$

$$\beta = \beta_0 + \beta_1 \log k \qquad (4.2b)$$

$$\gamma = \gamma_0 + \gamma_1 \log k \qquad (4.2c)$$

Substituting the expressions on right hand sides of (4.1a-c)) into equation (4.1) yields:

$$\ln CO2 = (\alpha_0 + \alpha_1 \log k) + (\beta_0 + \beta_1 \log k) \ln Y + (\gamma_0 + \gamma_1 \log k)\ (\ln Y)^2 + U \quad (4.3)$$

Thus, we can see that foreign to domestic owned capital ratio enters into the EKC as a moderator. EKC hypothesis will hold for the given data set if the rate of change in CO_2 emission with respect to per capita income is positive up to certain level of capita income, say Y^*, and thereafter the rate of change in CO_2 emission with further increase in income become negative. Thus, consider the first and second derivatives on both sides of equation (4.3):

$$\frac{\partial \ln CO2}{\partial \, Ln\, Y} = \beta_0 + \beta_1 k \ + 2\ (\gamma_0 + \gamma_1 \log k)\, Ln\, Y \quad (4.4)$$

$$\frac{\partial^2 \ln CO2}{\partial (Ln\, Y)^2} = 2\gamma_0 + 2\gamma_1 \log k \quad (4.5)$$

Equation (4.3) shows that CO_2 emission in general depends on the ratio between foreign and domestic owned capital stock unless all the parameters associated with the ratio k are equal to zero. More specifically, equations (4.4) and (4.5) indicate how the slope and curvature of EKC are affected by k. What happens to the location, slope and curvature of EKC due to the presence of capital ratio in the EKC equation will depend on the realized permutation of the signs and magnitudes of the parameter estimates. For example, EKC hypothesis will hold if $\beta_0 + \beta_1 k > 0$ and $\gamma_0 + \gamma_1\ k < 0$ over the entire range of the capital stock ratio k. At this stage it is not worthwhile to go in details of the possible outcomes regarding the shape of EKC.

Now consider the critical level Y^*, which is the turning point of the inverted U-shaped relationship in EKC. Setting the first derivative in equation (4.4) equal to zero and solving for the critical level of output, we obtain the following threshold level of output that represents.

$$\ln Y^* = -\frac{1}{2}\frac{\beta_0 + \beta_1 \log k}{\gamma_0 + \gamma_1 \log k} \quad (4.6)$$

This equation shows that the turning point of EKC also depends on the presence of foreign owned capital. In what direction foreign owned will change the turning point depends on relative magnitudes of four parameters as shown by the derivative given below.

$$\frac{\partial \operatorname{Ln} Y^*}{\partial \log k} = \frac{1}{2} \frac{\beta_0 \gamma_1 - \gamma_0 \beta_1}{(\gamma_0 + \gamma_1 \log k)^2} \tag{4.7}$$

It is evident from above that the location, slope, curvature and turning point of the EKC is the function of capital stock along with the values of other parameters.

Finally, to avoid misspecification of the model, equation 2.3 is extended by incorporating other (control) variables in our equation. The literature proposes various potential control variables and we consider the four most commonly used variables following, for example, Balogh (2022), Eisen and Brown (2022), Hill et al. (2021), Koch and Kaplan (2022), Lawrence et al. (2022), Liu et al. (2019), Pendrill et al. (2019), Sebatian et al. (2022), Stavropoulos et al. (2022). These variables are the proportion of geographic area covered under forests, shares of manufacturing and agriculture outputs in GDP and trade openness (export plus import to GDP ratio), denoted respectively by Forest, Man, Agri and Trade. With the addition of these variables, equation (4.3) to be estimated over panel data becomes:

$$\begin{aligned} \log CO2_{it} = {} & \alpha_0 + \beta_0 \log Y_{it} + \gamma_0 (\log Y_{it})^2 + \alpha_1 \log k_{it} + \beta_1 \log k_{it} \log Y_{it} \\ & + \gamma_1 \log k_{it} (\log Y_{it})^2 + \theta_1 Forest_{it} + \theta_2 Man_{it} + \theta_3 Agr_{it} \\ & + \theta_4 Trade_{it} + \lambda_i + \phi_t + \varepsilon_{it} \end{aligned} \tag{4.8}$$

where the subscripts i and t indicate country and year respectively.

In equation (4.7) λ_i and ϕ_t represent the country and period effects that can be deterministic or stochastic components. If λ_i are treated as deterministic (stochastic) component, the model is referred to as country Fixed (Random) Effects model. Similarly, deterministic (stochastic) treatment of the components ϕ_t is akin to period Fixed (Random) Effects model.

4.4 Data Description and Variable Construction

Given the limited availability of the required data, the study relies on the panel of 157 countries for the period of 1990-2018.

Since no direct data on capital stock are available, we construct the two series separately for each country using the data on investment flows and applying perpetual inventory method of transformation. For the domestic capital we rely on the data on gross fixed capital formation (the same as gross physical investment), while for the foreign capital stock we use foreign direct investment. Both the investment series are measured in constant PPP 2011 US$.

According to Herberger's (1978) approach if for a given period capital-output ratio is constant then the capital and output growth rates will be the same. Thus, denoting investment flow and capital stock of country i in period t by I_{it} and K_{it} respectively, and the growth rate of capital stock and rate of capital depreciation by g and δ respectively, we can write.

$$I_{it} = \Delta K_{it} + \delta K_{it-1} = \left(\frac{\Delta K_{it}}{K_{it-1}} + \delta\right) K_{it-1} = (g + \delta) K_{it-1}$$

It follows that the capital stocks in the initial and subsequent periods are given by:

$$K_{it-1} = \frac{I_{it}}{g + \delta} \tag{4.9}$$

$$K_{it} = (1 - \delta) K_{it-1} + I_{it} \tag{4.10}$$

Using this method we construct two capital stock series, one from domestic investment and one from FDI net inflows and denote them by K_{it}^{d} and K_{it}^{f} respectively.

Data on the other variables are directly available from the well-known sources. The lists of variables and their source are shown in Table 4.2.

Table 4. 2: Variables, Notations, Measurement Units and Data Sources

Variables	**Abbreviation**	**Unit of measurement**	**Data source**
Carbon dioxide emission	CO_2	Kilogram per capita	Global carbon project
GDP	Y	Constant PPP 2011 US dollars per capita	*World Development Indicators* (*WDI*)
Foreign Direct investment (FDI)		Constant PPP 2011 US dollars	*WDI*
Gross fixed capital formation (constant PPP 2011 US$)		Constant PPP 2011 US dollars	*WDI*
Foreign capital stock	K^f	Constant PPP 2011 US dollars	Constructed
Domestic capital stock	K^d	Constant PPP 2011 US dollars	*Constructed*
Foreign-to-domestic capital stock ratio	k		*Constructed*
Agriculture	Agr	Shares of agricultural sector in GDP	*WDI*
Manufacturing	Man	Shares of industrial sector in GDP	*World Development Indicators* (*WDI*).
Forest area	Forest	Percentage of area covered under forest.	*WDI*
International trade	Trade	Trade Percentage of GDP	*WDI*
Carbon dioxide emission	CO_2	Kilogram per capita	Global carbon project
GDP	Y	Constant PPP 2011 US dollars per capita	*World Development Indicators* (*WDI*)
Foreign Direct investment (FDI)		Constant PPP 2011 US dollars	*WDI*
Gross fixed capital formation (constant PPP 2011 US$)		Constant PPP 2011 US dollars	*WDI*
Foreign capital stock	K^f	Constant PPP 2011 US dollars	Constructed
Domestic capital stock	K^d	Constant PPP 2011 US dollars	*Constructed*
Foreign-to-domestic capital stock ratio	k		*Constructed*
Forest area	Forest	Percentage of area covered under forest.	*WDI*
Agriculture	Agr	Shares of agricultural sector in GDP	*WDI*
Manufacturing	Man	Shares of industrial sector in GDP	*World Development Indicators* (*WDI*).
International trade	Trade	Trade Percentage of GDP	*WDI*

4.5 Results and Discussion

Equation (4.8) is initially estimated by various techniques including Pooled Least Squares (PLS) model, Fixed Effects Model (FEM) and Random Effects Model. (REM) Thereafter, appropriate tests are applied to choose between the alternative models. If the time invariant variables are not incorporated in the model, then the simple PLS estimators are most likely to be biased and inconsistent since error terms of the equation are expected to be correlated with the measurement errors in unobserved variables. In case the dependent variable is correlated with the omitted variables, the REM would produce biased and inconsistent estimators, while the FEM would yield unbiased and consistent estimators. When the omitted variables are not correlated to the dependent variable, both the FEM and REM give unbiased estimators, but the latter model gives more efficient estimators than the former.

Table 4. 3: Results of Tests for Model Selection

Test Type	**P-Value of Test Statistic**	**Conclusion**
LM Test: Breusch-Pagan Honda King-Wu Standardized Honda Standardized King-Wu	 0.000 0.000 0.000 0.000 0.000	Country random effects are <u>not equal to zero.</u>
LM Test: Breusch-Pagan Honda King-Wu Standardized Honda Standardized King-Wu	 0.000 0.000 0.000 0.000 0.000	Period random effects are not equal to zero.
Hausman Test: Chi-square statistics	 0.000	The null hypotheses that Random effect model(country) is an appropriate model is rejected in favour of Fixed effects model
Hausman Test: Chi-square statistics	 0.000	The null hypotheses that Random effect model (period) is an appropriate model is rejected in favour of Fixed effects model.
Redundant Fixed effect test: Chi-square statistics F-statistic	 0.000 0.000	Country fixed effects are not equal to zero
Redundant Fixed effect test: Chi-square statistics F-statistic	 0.000 0.000	Period fixed effects are not equal to zero
Overall Conclusion	Country Fixed Effects model appears most appropriate.	

Table 4.3 summarizes the results of these tests. The first two rows of the table after the heading row show results of LM test to choose between PLS and REM. The p values indicate that in both cases the null hypotheses that country and time random effects are zero, is rejected at 1% significance level. Consequently, the PLS model is rejected in favour of the two-way REM.

In the third and fourth rows we present the outcome of Wald test to choose between PLS model and FEM. Here again the former model is rejected in favour of the latter consisting of country and period fixed effects.

This leaves us with FEM and REM and to choose between the two we apply Hausman-Wu test. The next two rows of the table show that the null hypotheses that REMs are more appropriate than the comparable FEMs are rejected at 1% significance level. So, we conclude that FEM including both the country and period effects is the most appropriate model for our estimation.

Thus, equation 4.8 is estimated as FEM and the parameter estimates are shown in the first column of results. However, to check robustness of the results the same equation is also estimated alternatively by following the other options. The results are presented in Table 4.4, which indicates that the parameter estimates are remarkably robust across the alternative modelling options with only one case of change in the sign of a parameter. That is, the estimated coefficient of the interaction term $k*Y^2$, which is positive in all the models, turns negative in the FEM considering period fixed effects only.

The overall performance of the estimated model (4.8) is quite good as indicated by the signs and significance of parameter estimates and the values of R-square and F-statistic. It is also noteworthy that all the parameters that directly relate to EKC or PHH are statistically significant under all the modelling options.

Given the above observations, we can concentrate on the results of our chosen model, that is the FEM including both the country and period effects. The signs of the crucial parameters are either according to theoretical expectations or can be justified. The coefficient of the log of per capita GDP is positive, while the coefficient of the squared term is negative, and both the coefficient are statistically significant. Thus, if we assume that the slope parameters of EKC do not depend on the capital ratio k, that is if we set $\beta_1 = \gamma_1 = 0$, that is if we consider a representative country where the composition of capital stock with respect to foreign vs domestic ownership does not matter in pollution emission, the EKC will hold for this country.

In this hypothetical situation the critical level of per capita GDP at which the EKC changes its slope from positive to negative can be estimated by setting the $\beta_1 = \gamma_1 = 0$ in equation (4.6). This would yield the turning point of EKC at $\ln Y^* = 8.455$. This implies that, the EKC changes its direction at the per capita income equal to US$

4700 measured in terms of 2011 PPP dollars. This level of per capita GDP is approximately at the 31st percentile of the per capita income series in the entre sample. This per capita income falls in the range of low-middle income countries and is approximately equal to the per capita income of China in the year 2003, India and Pakistan in 2015, Philippines in 2005, Ukraine in 2000. and Vietnam in 2011.

Moving to the most relevant part of the results are shown in Table 4.4, consider the signs and significance of the three parameter estimates associated with foreign owned to domestic capital ratio. First, note that the coefficient of the variable $\log k$ is positive and marginally significant, though in three other specifications it appears quite significant. A simple interpretation of this parameter estimate is that foreign capital contributes to CO_2 emission independent of the output. For example, for every ten percent increase in the foreign owned to domestic capital ratio, CO_2 emission increases by about 1.12 percent, which is not a too high impact.

Table 4. 4: The Regression Results

Independent variables	Model Type				
	County Period FEM	**Period FEM**	**Country FEM**	**Country REM**	**Pool Least square**
Intercept	-14.0350 (-12.96***)	-13.7268 (-21.12***)	-12.7828 (-11.90***)	-14.0878 (-14.38***)	-13.6783 (-21.15***)
Log per capita GDP ($\log Y$)	4.5033 (18.73***)	4.2520 (26.91***)	4.2409 (17.81***)	4.3461 (19.75***)	4.1846 (26.65***)
$(\log Y)^2$	-0.2663 (-15.76***)	-0.2667 (-19.06***)	-0.2436 (-14.78***)	-0.2514 (-16.12***)	-0.2553 (-18.54***)
Log of foreign capital to domestic capital ratio ($\log k$)	0.1124 (1.76*)	0.6686 (11.02***)	0.1199 (1.89*)	0.1661 (2.74***)	0.6548 (10.87***)
$\log k * \log Y$	-0.0338 (-4.19***)	-0.1006 (-13.40***)	-0.0308 (-3.88***)	-0.0429 (-5.67***)	-0.1003 (-13.52***)
$\log k * (\log Y)^2$	0.0020 (7.80***)	-0.0028 (-12.17***)	0.0014 (6.20***)	0.0018 (8.17***)	0.0026 (11..35***)
Proportion of area covered under forests (*Forest*)	-0.0167 (-6.49***)	-0.0050 (-11.66***)	-0.0134 (-5.49***)	-0.0071 (-4.95***)	-0.0048 (-11.28***)
Share of manufacturing sector in GDP (*Man*)	0.0059 (3.23***)	0.0086 (5.25***)	0.0070 (3.93***)	0.0113 (6.57***)	0.0111 (6.84***)
Share of agricultural sector in GDP (*Agr*)	-0.0021 (-1.41)	-0.0103 (-6.71***)	-0.0015 (-1.04)	-0.0017 (-1.203)	-0.0091 (-5.95***)
Trade to GDP ratio (*Trade*)	0.00014 (0.54)	0.0018 (7.41***)	0.0003 (1.03)	0.0004 (1.430)	0.0020 (8.45***)
R-squared	0.9756	0.8760	0.9749	0.3939	0.8711
Adjusted R-squared	0.9743	0.8748	0.9737	0.39.25	0.8708
F-statistic	753.7***	724.0***	861.8***	285.9***	2868.9***
Note: The statistics significant at 10% and 1% levels are indicated by * and *** respectively.					

However, more useful results are associated with the interaction terms involving foreign owned to domestic capital ratio and the two per capita GDP variables. The coefficient of the interaction term $\log k * \ln Y$ is significantly negative, while the coefficient of $\log k * (\ln Y)^2$ is significantly positive. Therefore, as the value of foreign to domestic capital ratio increases, the absolute values of slope and curvature of EKC decrease, or in simple terms, EKC becomes flatter.

The magnitudes of the three parameters associated with foreign to domestic capital ratio are such that for the entire range of per capita income in the given sample, the higher capital ratio corresponds to lower CO_2 pollution. For further detail, we explain the role of foreign to domestic capital ratio in shaping the EKC with the help of graphs. For this purpose, we set the values of the four control variables equal to their respective sample means and rewrite equation (4.8) in its estimated form as follows.

$$\log \widehat{CO2} = \pi_0 + \hat{\alpha}_1 \log k + \left[\hat{\beta}_0 + \hat{\beta}_1 \log k\right] \log Y + [\hat{\gamma}_0 + \hat{\gamma}_1 \log k] (\log Y)^2 \quad (4.11)$$

where

$$\pi_0 = \hat{\alpha}_0 + \hat{\theta}_1 \overline{Forest} + \hat{\theta}_2 \overline{Man} + \hat{\theta}_3 \overline{Agr} + \hat{\theta}_4 \overline{Trade}$$

Now to observe the sensitivity of EKC to the foreign to domestic capital rate k, we draw a set of EKCs for alternative values of k. These values of k are selected from our sample in such a way that holds all the characteristics of the series from the member countries under our investigation. The first value is the average of the first five values, the second value is the 10th percentile, the third is the 90th percentile and the fourth is the is the average of last five values. Corresponding to these values of k we draw four EKCs which are shown in Figure 4.1.

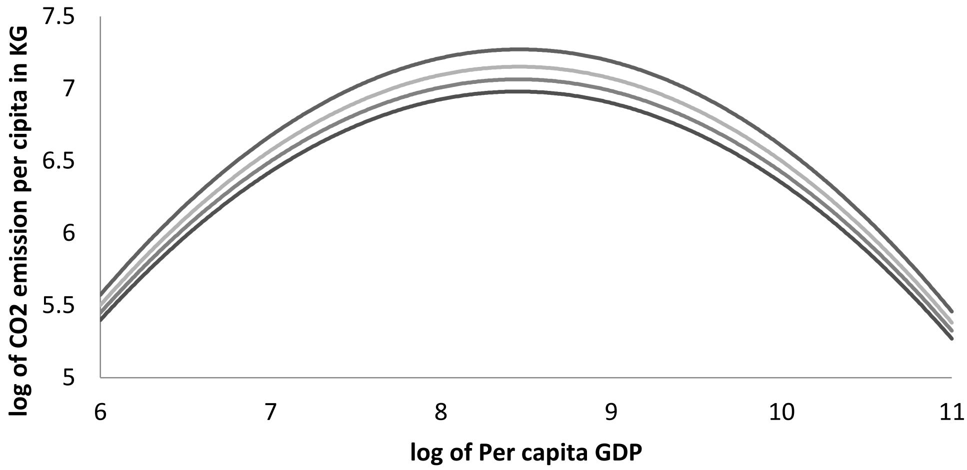

Figure 4. 1: EKCs with Alternative Values of Capital Ratio k

(The lower curve corresponds to higher value of k.)

The figure shows that holding all the control variables equal to their respective sample means, EKC hypothesis remains valid at all the levels of k. That is, irrespective of the extent to which capital stock in a country is accumulated through FDI, increase in per capita income results in increase in pollution emission at diminishing rate and the emission is expected to decline ultimately when the per capita income exceeds some threshold level.

The figure also shows that as the value of k is increased, the EKC becomes flatter and shifts downward. Although the extent of this shift is not sizable, we can nevertheless conclude the Pollution Heaver Hypothesis stands rejected. As for the Pollution Halo Hypothesis, we can conclude that sufficient evidence is not found to reject this hypothesis. This is a powerful result and is in contradiction with most of the empirical evidence based on data sets covering a large number of countries.

We further observe that the turning point of EKC is also reduced as the value of k increases. Thus, on average the presence of foreign owned capital not only reduces the CO_2 emission at all levels of income, but it also helps turn the direction of income-pollution relationship towards the right direction earlier in the process of growth.

Further, to quantify the effect of foreign capital on CO_2 emission, we again rewrite equation (4.8) by setting all the control variables as well as per capita GDP equal to their respective sample means. Variables. This leaves only the capital ratio a variable. The resulting relationship is given by.

$$\log \widehat{CO2} = \hat{\phi}_0 + \hat{\phi}_1 \log k \tag{4.12}$$

where

$\hat{\phi}_0 = \hat{\alpha}_0 + \hat{\beta}_0 \log \bar{Y} + \hat{\gamma}_0 (\log \bar{Y})^2 + \hat{\theta}_1 \overline{Forest} + \hat{\theta}_2 \overline{Man} + \hat{\theta}_3 \overline{Agr} + \hat{\theta}_4 \overline{Trade}$

$\hat{\phi}_1 = \hat{\alpha}_1 + \hat{\beta}_1 \log \bar{Y} + \hat{\gamma}_1 (\log \bar{Y})^2$

Equation (4.12) is used to estimate the values of CO_2 emission against the alternative values of k and the result is plotted in Figure 4.2, which shows a non-linear negative relationship of per capita CO_2 emission with the foreign to domestic capital ratio. Since the value $\hat{\phi}_1$ is negative we confirm the negative relationship between CO_2 emission and the capital ratio. The estimated per capita CO_2 takes asymptotically large value when k approaches zero and approaches towards zero as the value of k approaches infinity. To have some idea about the quantitative impact of foreign owned capital on CO_2 pollution, we put a few specific values of k in equation (4.12) and find that, for example, if the foreign capital increases from one percent of domestic capital to 100 percent, the per capita CO_2 emission will decline by 21.3% and if the foreign capital increases from one percent of domestic capital to 10 times, the decline in per capita CO_2 will be 33.7%.

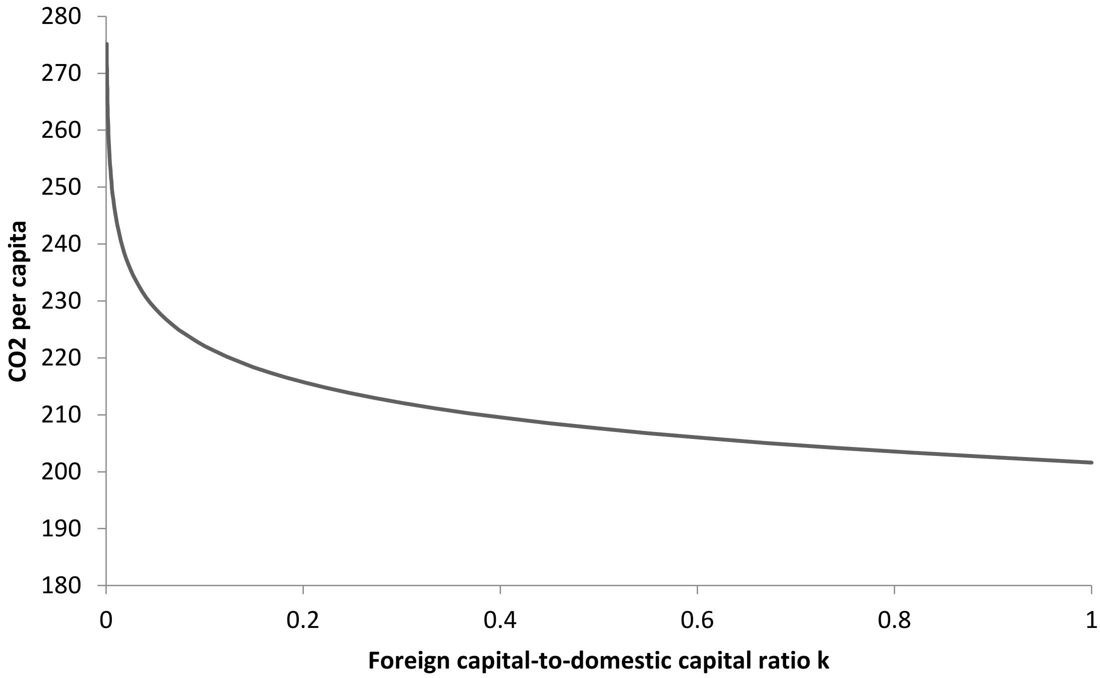

Figure 4. 2: Relationship of Per Capita CO_2 Emission with Foreign to Domestic Capital Ratio k

We now briefly discuss the impacts of control variables on the CO_2 emission. The percentage of total land area covered under forests (*Forest*) has negative and statistically significant relationship with the CO_2. The estimated regression coefficient shows that, for example, increase in the forest area by 10 percentage point will help reduce CO_2 by about 16.7%, which confirms the already established and extraordinary importance of forests in preserving environment.

Contrary to forest, the share of manufacturing sector in GDP (*Man*) shows a positive and significant relationship with CO_2. The value of estimated coefficient shows that one percentage point increases in the share of manufacturing output in GDP results in 0.6 percent increase in CO_2 emission. This clearly indicates that as manufacturing sector in a country grows, it will need more energy, and when more energy is consumed, then there will be more CO_2 emission.

The first column of Table 4.4, which represents our selected model, shows negative but insignificant impact of the share of agricultural sector in GDP (*Agr*) on the CO_2 emission, though in two other columns the relationship is statistically significant. In any case, the insignificant relationship as per our selected model implies that with mechanization of agricultural sector and energy intensive farming almost offsets the benefit of green environment provided by agricultural activity.

Finally, the table shows that trade as ratio to GDP has positive association with the CO_2 emission, but the relationship is insignificant in the selected model.

4.6 Conclusion

In this chapter we examined the impact of foreign-owned capital stock on the environmental degradation by extended the EKC framework. This is the first study to replace FDI by foreign owned capital stock in testing the PHH. In this context EKC is extended to allow the moderating role of foreign-owned capital in the relationship of per capita CO_2 emission with per capita income. The moderating variable is the ratio of foreign-owned capital stock to the domestic-owned capital stock. The two capital stock series are estimated using perpetual inventory method.

Besides per capita income and the capital stocks ratio, four control variables are also included in the model, which are the percentage of total land area covered under forests, the shares of manufacturing and agricultural outputs to GDP and trade openness (exports plus imports as percentage of GDP.

Empirical analysis is based on a panel data set comprising 157 developed and developing countries and covering the period 1990 to 2018. The regression model, linear in parameters, is estimated by various panel options and Fixed Effects Model including both the country and period effects is selected n the basis of standard testing procedure.

The most important result that comes out of the analysis is that PHH is rejected, and CO_2 emission is positively correlated with the foreign-owned to domestic-owned capital stock. In other words, foreign capital is found to cause less pollution as compared to domestic owned capital. The magnitude of this impact is, however, moderate.

Since the above result goes against most of the empirical studies covering a large number of countries, more rigorous analysis would be required to change the prevalent opinion. Nevertheless, the main contribution of the study is to look at the PHH from a new angle and to demonstrate how this novelty can alter the prevalence of belief. As several regional and country level studies have also pointed out, the FDI recipient counties have to focus on their own environment regulations and governance structure rather than finding solace in believing PHH.

Chapter 5

CONCLUSION AND POLICY IMPLICATIONS

5.1 Summary and conclusion

Carbon dioxide (CO_2) emission as a byproduct of economic development has emerged a serious global environmental problem over the past several decades. Various dimensions of environmental pollution relating to its causes and consequences have been analyzed in scientific studies, but a major part of recent literature focuses on empirical relationships of CO_2 emission with economic development. Two celebrated works on this line relates to Environmental Kuznets Curve (EKC) and Pollution Haven Hypothesis (PHH). The EKC states that per capita CO_2 emission forms an inverted U-shaped relationship with per capita income, while the PHH states that the by shifting their dirty industries to developing and emerging economies, the developed countries are essentially outsourcing their share of pollution as well.

This thesis extends empirical work surrounding EKC in three dimensions, taken up in three different essays with the purpose to study and understand the nature of relationship of per capita CO_2 emission with per capita income in a broader context. These dimensions include the role of governance, reconsideration of the relationship between pollution emission and income and reconsideration of PHH in EKC framework by shifting the focus from foreign investment flow to foreign owned stock of capital. The empirical work is based on panel data for 160 countries over the period 1996 to 2018.

The first essay explores the role of governance as a moderating factor in the standard EKC equation. The results of this essay show that governance plays crucial role in shaping the EKC in terms of its location, slope and curvature. More specifically, the highest EKC corresponds to lowest governance index and lowest EKC corresponds to the highest governance index. Furthermore, the decline in pollution along with good governance level is unbalanced. At the rising portion of EKC, marginal benefits of better governance are quite small, whereas at falling phase of EKC the marginal benefits are large. This result shows that good governance in lower income countries is less effective in mitigating pollution compared to the high-income countries. Another useful result is that better governance practices can also help countries reduce the critical level of per capita income at which pollution emission starts declining with economic development.

In the second essay standard quadratic equation representing EKC is extended to a quadratic Spline Function, which is a set of piece-wise regression equations separated by per capita income thresholds with smoothing restrictions on the level and slope of the curve. Thus, the per capita income range is classified into 11 intervals separated by 10 thresholds (or knots) The empirical results show that the relationship between income and pollution does not specifically follow inverted U-shaped curve. It rather follows an M-shaped path having two peaks, wherein at the second peak CO_2 emission is substantially lower than the level at the first peak.

The prominent countries that lie in the rising portion of the curve before the first peak are mostly poor and low-income countries from Africa, Asia, Latin (South) America and some East Europe, Bangladesh, Congo, India, Nigeria, Pakistan, Philippines, and Vietnam. In contrast the countries that lie in the falling portion of the curve after the first peak are mostly emerging and middle-income countries including Brazil, Canada, China, Colombia, Egypt, Indonesia, Japan, Mexico, Russia, South Africa, South Korea, and Turkiye. The countries that lie on the second rising portion of the curve include rich countries like Denmark, Hong Kong, Norway, Singapore, Switzerland, The Netherlands, United States of America, and some of the oil-rich Middle Eastern countries. Finally, only four countries; Qatar, Kuwait, UAE, and Luxembourg; touched the range of per capita income beyond the second peak. Although, the positive relationship between per capita income and CO2 emission indicates negative relationship between per capita income and environmental quality, it does not necessarily means that environmental quality is considered as inferior good. Rather compromise on environmental quality is the cost of raising living slandered that the society is willing to bear in terms of negative externality.

The essay concludes from the above observations that since for all practical purposes the portion of the curve beyond the second peak is not widely observed; it is only a theoretically predicted behavior which indicates that when world's rich economies grow to achieve very high per capita income levels, technological advancement would make it possible to maintain luxurious living standards even with low energy intensity and with better ways to manage pollution emission.

Chapter 4 investigates the validity of PHH in the EKC framework. A novel contribution of this essay is that unlike the past literature it focuses on foreign-owned capital stock rather than foreign investment inflow as the variable that matters in pollution emission. The composition of capital stock with respect to foreign versus domestic ownership enters into the EKC equation as a moderator. The empirical results show that EKC can be shifted downwards by increasing the proportion of foreign-owned capital stock; therefore, the PHH stands rejected.

5.2 Policy implication of the study

Based on findings of this thesis, a number of policy implications for countries, researchers, policy makers can be drawn.

Speedy corrective measures are necessary to mitigate human caused environmental degradation and climatic change. Since the impact of good governance on environment is small and economic growth takes precedent over environmental in the context of growth-environment trade-off in poor countries, these countries may be encouraged to adopt direct measures of environmental protection and ecological preservation with a long-term perspective. For example, concessional loans and aid packages may be made conditional upon environment-friendly technology and ecological preservation.

In middle-income countries the role of good governance is more visible and these countries may prioritize their policies considering investment in environment-protection technology and investment in environment-protection governance. Assessing the relative strengths of the two strategies would be useful for working out the optimal policy mix.

Good governance is most productive in controlling pollution in in upper-middle and high-income countries. Although most of these countries also score well on governance, yet there are exceptions and there is scope for improvements in institutions. Investment in institutions in such countries is expected to yield maximum dividends for a clean environment.

Policy makers, experts, and countries should first make a feasibility study of any foreign capital stock import and asses their pollution emission intensity. The countries should allow all such foreign investments that make more efficient use of energy. As several regional and country level studies have also pointed out, the FDI recipient counties have to focus on their own environmental regulations and governance structure rather than hiding pointing fingers towards Pollution Haven Hypotheses.

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Appendix

List of countries Alphabetically

Afghanistan Albania Algeria Angola Argentina Armenia Australia Austria Azerbaijan Bahrain Bangladesh Barbados Belarus Belgium Belize Benin Bhutan Bolivia Bosnia and Herzegovina, Botswana Brazil Brunei Darussalam, Bulgaria Burkina Faso Burundi Cambodia Cameroon	Canada Central African Republic Chad Chile China Colombia Comoros Congo, Dem. Rep Congo, Rep Costa Rica Cote d'Ivoire Croatia Cyprus Czech Republic Denmark Dominican Republic Ecuador Egypt, Arab Rep El Salvador Equatorial Guinea Eritrea Estonia Fiji Finland France Gabon	Gambia Georgia Germany Ghana Greece Guatemala Guinea Guinea-Bissau Guyana Honduras Hong Kong SAR, China Hungary Iceland India Indonesia Iran, Islamic Rep. Iraq Ireland Israel Italy Jamaica Japan Jordan Kazakhstan Kenya Korea, Rep. Kuwait

Lao PDR Latvia Lebanon Lesotho Liberia Libya Lithuania Luxembourg Macao SAR, China North Macedonia Madagascar Malawi Malaysia Mali Malta Marshall Islands Mauritania	Netherlands New Zealand Niger Nigeria Norway Oman Pakistan Palau Panama Papua New Guinea Paraguay Peru Philippines Poland Portugal Romania Russian Federation	Spain Sri Lanka St. Lucia Sudan Sweden Switzerland Tajikistan Tanzania Thailand Timor-Leste Togo Tonga Tunisia Turkey Turkmenistan Ukraine United Arab Emirates

Mauritius Mexico Moldova Mongolia Montenegro Morocco Mozambique Myanmar Namibia Nepal	Rwanda Saudi Arabia Senegal Serbia Seychelles Sierra Leone Singapore Slovak Republic Slovenia Solomon Islands South Africa	United Kingdom United States Uruguay Usbekistan Vanuatu "Venezuela, RB" Vietnam West Bank and Gaza Zambia Zimbabwe