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Analyzing Environmental Kuznets Curve and Pollution Haven Hypothesis in India in the Context of Domestic and Global Policy Change

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Abstract
While the notion of Environmental Kuznets Curve (EKC), which relates economic development to pollution, is well established, there is controversy about its shape, incidence and determinants. Moreover, there is an avowed relationship between economic development and international trade. This leads to the conceptualization of the trade-environment triangle between type of economic development, environment and trade and investment. Therefore, the study of EKC is incomplete without accounting for the pollution haven hypothesis (PHH). The original EKC literature restricts itself to a quadratic form whereas the new literature establishes that a cubic form is more appropriate. Also, the traditional EKC literature with few exceptions (Murthy and Bhasin, 2016) is stand-alone and does not incorporate PHH. Against this backdrop, we evolve a framework, which is based on both the critical evaluation of extant studies and an extension of these studies to the Indian context. We model EKC using alternative model specifications to bridge the gap between conventional and modern EKC literature. We further synthesize a model that combines the effect of EKC as well as PHH in the Indian context.

We substantiate a cubic form of EKC for India for the time period 1991 to 2014. With aggregate CO_2 emissions as the dependent variable, the linear (2.34E-06), quadratic (-1.2E-18) and cubic (2.64E-31) terms are all significant with the right signs, which confirms an N-shaped EKC for India. We also validate PHH for India in our model integrating EKC and PHH. Even with per capita emissions as the dependent variable, existence of an N-shaped EKC is established. In this case however, evidence on the cubic term is rather weak (p-value = 0.1250), which points towards the difference in the socio-psychological factors that influence the revival of the upturn in the case of India. Also, FDI has a smaller influence in per capita terms, but its coefficient is more significant, which means that we cannot ignore this phenomenon yet numerically its impact is much smaller. Our findings are in accordance with the new literature, which is the basis of the trade, environment and economic development triangle.

Keywords
Environment and Development, Environment and Trade, Environment and Growth, Environmental Kuznets Curve, Pollution Haven Hypothesis.

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K.V. Bhanu Murthy[1] and Sakshi Gambhir[2]

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While the notion of Environmental Kuznets Curve (EKC), which relates economic development to pollution, is well established, there is controversy about its shape, incidence and determinants. Moreover, there is an avowed relationship between economic development and international trade. This leads to the conceptualization of the trade-environment triangle between type of economic development, environment and trade and investment. Therefore, the study of EKC is incomplete without accounting for the pollution haven hypothesis (PHH). The original EKC literature restricts itself to a quadratic form whereas the new literature establishes that a cubic form is more appropriate. Also, the traditional EKC literature with few exceptions (Murthy and Bhasin, 2016) is stand-alone and does not incorporate PHH. Against this backdrop, we evolve a framework, which is based on both the critical evaluation of extant studies and an extension of these studies to the Indian context. We model EKC using alternative model specifications to bridge the gap between conventional and modern EKC literature. We further synthesize a model that combines the effect of EKC as well as PHH in the Indian context.

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In terms of EKC the policy implication is that gains of green technologies are being wiped out by over-consumption of environmentally unfriendly goods. In terms of PHH the policy recommendation is clear that indiscriminate introduction and encouragement of FDI that raises the level of pollution is not welcome in India.

JEL Classification: F18, F64, O44, Q56.

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1. INTRODUCTION

There have been vast changes in global policy since the emergence of WTO. Efforts have been made to narrow down the divergence between developed and developing countries and create a level playing field, through removal of tariff and non-tariff barriers and establishment of certain agreements, mainly TRIPS and TRIMs. Although the initial impetus came globally during the late eighties, in India it happened in 1991. During this period, the Indian economy was deregulated wherein various controls such as industrial licensing, exchange rates and interest rates were deregulated. There is a clear association between opening up, liberalization, deregulation, growth in trade and the international business environment brought about by the alignment of domestic policy with international policy.

There is an intertwining of technology, investment, industrialization, growth and pollution within India, due to a complex set of global and domestic policies adopted after liberalization and globalization. On the one hand, liberalization and domestic policy has encouraged industrialization and growth but on the other hand it has encouraged polluting industries and higher emissions leading to the emergence of the Environmental Kuznets Curve (EKC), which demonstrates that CO2 emissions increase with growth in per capita income (PCI) and fall when a sufficient threshold of PCI is achieved. Global policies initiated through WTO and other frameworks have resulted in Foreign Direct Investment inflows to India. This gives rise to the added dimension of environmental degradation, that is, Pollution Haven Hypothesis (PHH) in India.

Motivation

This entire gamut of factors has led to complex relationships between the three dimensions: economic development, trade and environment. Traditionally, the debate on economic development has been centered on the trade and development aspects. After the 1980s, particularly since the era of liberalization and globalization, the debate shifted to free trade, which transcended to reality only with the emergence of WTO. In recent times, however, the realization has dawned upon the world at large that the overarching issue is the environment leading to the emergence of a three-dimensional relationship between trade, environment and economic development. Figure 1 below illustrates the relationship between trade, economic development and the environment envisaged in the form of a global trade-environment triangle.

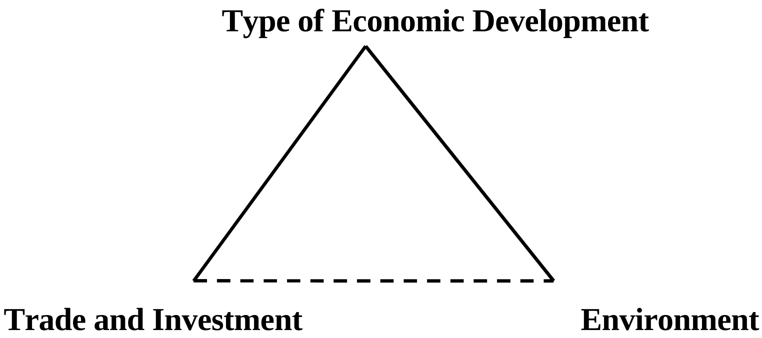

Figure 1. Trade-Environment Triangle (Murthy and Gambhir, 2017)

On one hand, we have the relationship between type of development and trade and investment; and on the other hand, we have the relationship between environment and type of economic development. With the help of these two broad relationships, we can examine the linkages between trade and environment. The kind of economic development that has resulted from liberalization and globalization, more particularly, is characterized by a high volume of trade (export + import), a high degree of urbanization and energy intensive industrialization (Jha and Murthy, 2006, p.12). Such a type of economic development has led to growth of multinationals and hence, foreign direct investment outflows. The multinationals tend to corner foreign trade, energy resources as well as urban resources. They, therefore lead to a peculiar model of growth, which in turn affects environment on the one hand and GDP growth on the other hand. In the past two or more decades, these dominance patterns have come to stay, thereby reinforcing the trade-environment triangle.

Furthermore, two of these broad relationships, one between environment and economic development; and the other between environment and trade and investment, could be comprehended in terms of two broad constructs. The former could be studied with the help of EKC while the latter could be studied with the help of PHH. In this work, we are specifically examining carbon dioxide (CO_2) emissions, which are a major indicator of environmental degradation; Gross Domestic Product (GDP), a proxy of economic development along with Foreign Direct Investment (FDI), which is a major determinant of international factors that affect the environment. These variables enable us to analyze the phenomena of EKC and PHH in the Indian context and model these two constructs with different model specifications while synthesizing a model that combines the effect of the two, for a robust analysis.

India's development strategy has shifted from import substituting industrialization to export oriented industrialization after the major domestic policy change towards liberalization. The policy of liberalization in India was largely an exercise in domestic decontrol but it also involved partial dismantling of trade barriers. This has led to the emergence of Home Country Multinationals to target developing countries like India to establish manufacturing hubs as export platform through assembly of semi-knock down (SKD) and completely knock down (CKD) kits. This involved international relocation of production or the introduction of FDI inflows in to India which was an otherwise closed economy. A vital dimension to the emergence of such global phenomena has been the increasing stringency in pollution control regimes in developed countries. They have been on the look out to exploit the relatively laxer policy environment in emerging market economies like India and continue to gain from employing greener technologies in their own countries while pushing polluting technologies to the developing countries. This happens as a result of global and domestic policy change and further complicates the matter, leading to PHH. We can therefore relate emergence of EKC with domestic policy change and PHH with global policy change.

Hence, the main motivation is to try and answer the questions:

1. Does EKC exist in the Indian context?
2. Does PHH exist in the Indian context?
3. Do these two phenomena exist as a joint hypothesis in the Indian context?

It is in the light of this, the following work is set.

Our ***broad objectives*** are:

- ✓ To test for the different forms of EKC in the Indian context.
- ✓ To test for the impact of PHH in the Indian context.
- ✓ To synthesize a model to test for the joint hypothesis of EKC and PHH in the Indian context.

Against this backdrop, we formulated the following **primary hypotheses**:

- There is no evidence to validate EKC in the Indian context.
- There is no evidence of re-linking hypothesis in the Indian context.
- There is no evidence to validate PHH in the Indian context.
- The joint hypothesis of EKC and PHH does not exist in the Indian context.

The rest of the study is organized as follows. Section 2 lays down the conceptual framework for EKC and PHH highlighting some crucial dimensions of the trade-environment relationship. Section 3 provides a brief review of the extant literature on EKC and PHH. Section 4 discusses the data sources and the methodology employed. Section 5 presents the analysis and results. Section 6 concludes.

2. CONCEPTUAL FRAMEWORK

The pattern of FDI growth is driven by trade being substituted by FDI; adoption of energy intensive technologies whose ownership lies with multinationals; and urbanization which results in industry rather than primary activity that is largely controlled by multinationals. Thus, the type of economic development (characterized by a high volume of trade, a high degree of urbanization and energy intensive industrialization) determines the pattern of growth and development of FDI on the one hand, and the emergence of pollution patterns, especially in the developing economies on the other hand. This means that multinationals' growth takes place in the home country, that is, the developed country and they are able to corner the fruits of the type of economic development in terms of trade and industrialization. In turn, they impose a pattern of environmental degradation and pollution in the entire global economy. This is also enabled by global policies. One of the implications of the level playing field, envisaged and promoted through WTO, is that FDI is allowed to enter anywhere that it pleases. This permits the perpetuation of certain global patterns in FDI as well as the nature of industry that is being spread through FDI. Here, it is necessary to disabuse ourselves of the notion that multinationals have advanced technologies and hence are likely to be more energy efficient and less polluting. Labor-intensive technologies are by themselves less polluting. Secondly, the type of industry which is being relocated from the home country to the host –

developing country is by design those polluting industries which are not sustainable in the home country (Murthy and Gambhir, 2017).

Literature has been treating the relationship between economic development and pollution levels through EKC in a rather uncomplicated manner, while viewing FDI as international relocation of production and not just a neutral capital flow, whereas there is a clear bias in the nature of capital flows.

Environmental Kuznets Curve (EKC)

According to the EKC hypothesis, environmental damage increases in the early stages of economic development, but diminishes once nations reach higher levels of income, suggesting that the relationship between income (economic development) and environmental degradation takes the shape of an inverted U (Figure 2). This happens because developed countries have the necessary technologies for pollution abatement and also the necessary capital for implementing such technologies.

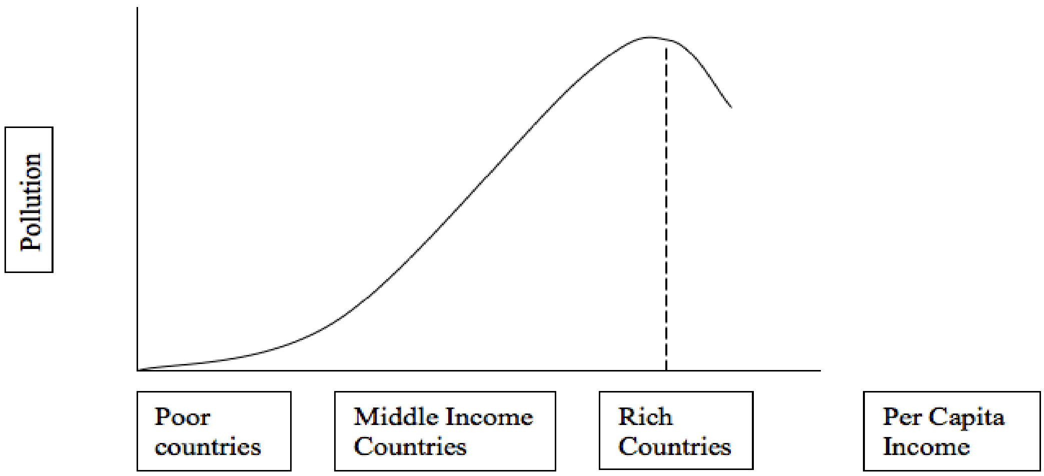

Figure 2. A hypothetical global EKC (Murthy and Bhasin, 2016)

The turning point in Figure 2 represents that level of income beyond which environmental degradation gets delinked from the process of economic growth. This is called the threshold level.

The De-linking and Re-linking Hypothesis

Some explanation for the EKC downturn is the explanation that comes from literature emanating from the developed countries themselves. It is argued that technology and capital, both of which developed countries have in abundance, are the main reason for establishing the de-linking hypothesis. De-linking refers to decoupling of environmental impacts from economic growth. The argument is that developed countries have the capital because they are capital intensive and that capital can buy green technologies. This leads to de-linking in the sense, when the developed countries go beyond a threshold, they can afford to harness such technologies, which are expensive but effective in reducing environmental degradation. Meanwhile, developing countries neither possess the technology nor do they have the necessary resources to implement these technologies. Further, developing overpopulated economies have two invariably negative features that are likely to aggravate the environmental problem, namely poverty and overpopulation. It is, therefore argued that developed countries alone have the potential to delink pollution from growth. Nevertheless, even if the de-linking hypothesis holds true, one could still doubt if the observed improvements in environmental quality would sustain in the long run. If such improvements could not be extrapolated into the future, delinking would only be a temporary phenomenon. This implies that there might come an income level, where there would be technological and economic upper bounds to improvements in environmental efficiencies. At this stage, environmental degradation and economic growth would be relinked again. This is referred to as the re-linking hypothesis (de Bruyn and Opschoor, 1997).

Pollution Haven Hypothesis (PHH)

It basically states that the emission reductions achieved in developed nations are partly the result of shifting “dirty” production to developing nations with lax environmental standards. When income and environmental degradation rise substantially, more severe environmental regulations would be imposed in an economy, inducing relocation of pollution intensive industries to developing countries with weaker environmental legislations. This would result in a ‘race to the bottom’ whereby developing nations lower their environmental and social standards in order to gain a competitive advantage (Bu et al., 2013). The outcome would be greater environmental damage in the developing nations.

The unfolding of globalization and inception of WTO led to the creation of a level playing field by narrowing down the divergence between developed and developing countries. This rendered some degree of commonness to nations, by virtue of which developed countries could consider the possibility of international relocation of production. At the same time, developed countries continued to experience mounting pressures to reduce their emissions levels due to stringent environmental regimes. These countries thus saw the level playing field as an opportunity to relocate production elsewhere and depress their emissions (Murthy and Bhasin, 2016). But it is important to note here that there are additional determinants to a country’s comparative advantage such as population density, size, absorptive capacity etc. Thus, to be able to make inferences about the patterns of trade, one would have to weigh the influences derived from the environmental policy against other determinants of trade.

Moreover, EKC, necessarily points out that the delinking hypothesis would be effective if and only if, further growth is delinked from pollution and since the home countries had failed to do so, it led to the relinking hypothesis (Jha and Murthy, 2003). So, as a strategy to deviate the relinking hypothesis, the developed economies resorted to transfer of polluting industries (pollution haven hypothesis) (Murthy and Bhasin, 2016). This completes the triangle between the type of economic development, FDI flows and pollution patterns.

3. LITERATURE REVIEW

The literature devoted to examining the three-dimensional relationship of economic development, trade and environment, is rather limited (Jha and Murthy, 2004; Murthy and Bhasin, 2016). There are many studies, which focus on examining the phenomena of EKC and PHH individually but fail to combine the effect of the two, in the realm of the trade-environment triangle at the global level. Shafik and Bandyopadhyay, 1992; Holtz-Eakin and Selden, 1995; Jha and Murthy, 2003; Babu and Datta, 2013; Zhao et al., 2013, examine the relationship between economic growth and environmental quality (EKC) using specific environmental indicators. While the conventional EKC studies validate a quadratic EKC, the modern EKC literature establishes that a cubic form of EKC seems more appropriate. Meanwhile, Taylor, 2005; Erdogan, 2013; Poelhekke and Ploeg, 2012; Kim and Adilov, 2011; Bu et al., 2013, explicate the theory behind PHH and its implications for the debate surrounding international trade flows and environmental regulations. Of the myriad literature devoted to examining EKC and PHH individually, the endeavors to synthesize a model combining the effect of two, specifically in the Indian context have been further limited (Pao and Tsai, 2011; Jayanthakumaran et al., 2012; Kanjilal and Ghosh, 2013). We, therefore attempt to examine this joint phenomenon through a framework, which is based on the following critical evaluation of extant literature and an extension of these studies to the Indian context.

The early EKC estimates showed that some important indicators of environmental quality such as the levels of sulfur dioxide and particulates in the air actually improved as incomes and levels of consumption went up. Since then, this theory has been tested and validated for certain countries using specific indicators of environmental degradation. But, there have been some key concerns:

- The inverted-U shape of EKC is taken for granted and empirically examined for countries by relating individual degraders with individual indicators of economic development. But, linking individual pollutants to the level of per capita income (as done in most cases) could produce misleading conclusions. Also, a country's per capita income maybe only an imperfect indicator of its development (Jha and Murthy, 2003).
- There are several econometric concerns. To begin with, the earliest studies were simple quadratic functions of the levels of income, which seemed rather inappropriate. Some studies used a cubic EKC in levels and found an N-shaped pattern. The standard EKC regression model assumed same income elasticity across all countries at a given level of income. Most studies used panel data attempting to estimate both the fixed and random-effects models, but only fixed effects could be estimated consistently. This implied that results based on a particular sample of data could not be extrapolated to other samples (Stern, 2004).
- Most empirical EKC studies have attempted to estimate the level of average income that would correspond to the threshold level of the typical EKC pattern, with the implicit assumption that world income is normally distributed. However, world income distribution is highly skewed with much larger number of people below world mean income than above it. Therefore, it is the median rather than mean income that is the relevant variable (Stern et al., 1996).
- The early-EKC literature implicitly assumed a uni-directional causality running from income to environmental degradation, thereby ignoring the rebound effects of energy efficiency (Kaika and Zervas, 2013).
- Also, validity of the EKC pattern has been contingent on the type of pollutant considered. The inverted-U shape has been supported mostly when the pollutants in question were associated with low and local short-term abatement costs such as sulfur dioxide, particulates, etc. No apparent patterns could be found for pollutants with long-term effects such as CO_2 emissions. (Kaika and Zervas, 2013).
- EKC studies have not given consideration to the consumption side of the economy. Hence, if the needs of domestic consumption were satisfied by imports, then this effect would not be taken into account in an EKC analysis focusing only on domestic production (Rothman, 1998; Cole, 2004; Jha and Murthy, 2004).

In the light of the aforesaid concerns, the validity of EKC as a universal phenomenon has remained questionable. Empirical analysis has revealed that it may apply to select pollutants and to certain countries assuming different forms (inverted-U, U shaped, N-shaped or monotonic).

Moreover, though the premise of PHH seems intuitive; evidence substantiating the same has been at best mixed. It continues to remain highly contentious in debates surrounding trade, foreign investment and environment.

The uncertainty surrounding its validity rests on some of these arguments.

- Capital abundant developed countries with investible resources and technology could attract polluting industries from developing economies to adhere to stricter environmental standards so there could be a possible reverse transfer of FDI from the developing countries to the developed world. However, this phenomenon of a so-called reverse transfer seems largely theoretical.
- Though industries seem likely to relocate from developed countries to the developing world, the environmental philosophy pursued by a firm also has some role to play. (Poelhekke and Ploeg, 2012). The multinationals with higher social responsibility were less likely to be attracted by a weak environmental regulation regime (Bu et al., 2013). Also, there has been evidence suggesting that foreign firms could export greener technologies to developing economies and be even less polluting than the domestic firms, referred to as the 'pollution halo' hypothesis (Kim and Adilov, 2011).
- A firm's investment location decision rests on many factors such as market potential, labor costs, capital abundance, political stability, infrastructure, cultural compatibility etc. Pollution abatement costs are not found to be a major influence in FDI decisions. In this sense, the pollution haven effect is present but PHH is not empirically supported (Erdogan, 2013).
- Against the 'race to the bottom' argument, it is reasoned that pressures to lower environmental standards are contingent on country-specific factors such as the extent of political lobbying, consumer sensitivity, level of government corruption etc. Thus, endogenous determination of environmental standards with respect to FDI could alter the results obtained under the exogeneity assumption (Erdogan, 2013).

In the light of these arguments, validation of PHH as a global phenomenon has been rather difficult. It has been justified for some pollutants and certain industries, but widespread evidence has been hard to find (Kim and Adilov, 2011; Bu et al., 2013; Al-mulali and Tang, 2013).

4. DATA AND METHODOLOGY

4.1. Data

Data for the study were sourced from the World Development Indicators, World Bank.

Time series data were collected for our two sets of variables; the dependent variable, namely aggregate CO_2 emissions (kt) in model A and CO_2 emissions per capita (metric tons) in model B along with the independent variables, namely, GDP (current US$) and FDI, net inflows (BOP, current US$) in model A, and GDP per capita (current US$) and FDI, net inflows (BOP, current US$) in model B, for the time period 1991 to 2014.

4.2. Methodology

Conventionally, EKC is measured either through aggregate CO_2 emissions or per capita CO_2 emissions (Murthy and Bhasin, 2016). The expected functional form is one where the underlying pattern of emissions is quadratic. The original literature restricts itself to such a form. This is on account of the delinking hypothesis. Such a relationship has been tested by various authors (Grossman and Krueger, 1993; Shafik and Bandyopadhyay, 1992; Cole et al., 1997, etc.). Sometimes the specifications in these works are couched in terms of per capita emissions (Shafik, 1994; Holtz-Eakin and Selden, 1995, etc.). However, some of the studies question the quadratic form, by arguing that the so-called delinking is followed by a phase of relinking (Jha and Murthy, 2003). This gives rise to an N-shaped EKC due to the relinking hypothesis. What literature does not state with some exceptions (Jha and Murthy, 2006), is that this relinking is not due to technology and investment but it is due to consumption, which increases disproportionately due to socio-psychological factors. Consequently, the new literature challenges the quadratic form of the EKC and clearly establishes that the EKC shows up as an N-shaped curve represented by a cubic form of the equation, explained through three phases. In the first phase, poorer countries, which have a lower level of consumption, lead to pollution because they cannot afford cleaner technologies. In the second phase, the middle-income level, the investment in cleaner technologies manifests in the form of a dip in the emissions. In the third phase, which is achieved at relatively higher levels of income, the benefit from cleaner technologies is outweighed by the degradation caused due to excessive consumption (Gambhir, 2017). Another dimension to the measurement issues is that the traditional literature on EKC with few exceptions (Murthy and Bhasin, 2016) is stand-alone and does not incorporate the pollution haven hypothesis.

Against this backdrop, our focus has been on evolving a framework (Table 1), which enables modeling of EKC through alternative model specifications and synthesizing a model that combines the effect of EKC and PHH in the Indian context.

Table 1. Framework for analyzing EKC-PHH in the Indian context

Dep. Var. / Model No.	Aggregate Carbon dioxide emissions (CO_2) (in kilotons) (A)	Per Capita Carbon dioxide emissions (CO_2PC) (in metric tons) (B)
1	Quadratic EKC	Quadratic EKCPC
2	Cubic EKC	Cubic EKCPC
3	Cubic EKC with FDI	Cubic EKCPC with FDI

In line with the above stated framework, we formulated the following estimating equations.

A. With aggregate carbon dioxide emissions (CO_2) (in kilotons) as the dependent variable

A.1. Quadratic EKC

Functional form: $CO_{2t} = f\,(GDP_t, GDP_t^2)$

Estimating equation

$$CO_{2t} = \alpha_1 + \beta_1\, GDP_t + \beta_2\, (GDP^2)_{\,t} + e_{t1} \qquad \ldots(1)$$

where

α_1 = intercept (initial level of aggregate CO_2 emissions)

β_1 and β_2 = indicators for testing the existence of a quadratic EKC with aggregate CO_2 emissions and GDP. The expected sign of β_1 is positive while that of β_2 is negative. If these coefficients turn out to be significant with these expected signs, it would confirm the existence of an inverted-U shaped relationship between aggregate CO_2 emissions and GDP for India over the time period 1991 to 2014

A.2. Cubic EKC

Functional form: $CO_{2t} = f(GDP_t, GDP_t^2, GDP_t^3)$

Estimating equation

$$CO_{2t} = \alpha_2 + \beta_3 GDP_t + \beta_4 (GDP^2)_t + \beta_5 (GDP^3)_t + e_{t2} \qquad \ldots(2)$$

where

α_2	=	intercept (initial level of aggregate CO_2 emissions)
β_3, β_4 and β_5	=	indicators for testing the existence of a cubic EKC with aggregate CO_2 emissions and GDP. The expected sign of β_3 and β_5 is positive while that of β_4 is negative. If these coefficients turn out to be significant with these expected signs, it would confirm the existence of an N-shaped shaped relationship between aggregate CO_2 emissions and GDP for India over the time period 1991 to 2014

A.3. Cubic EKC with FDI

Functional form: $CO_{2t} = f(GDP_t, GDP_t^2, GDP_t^3, FDI_t)$

Estimating equation

$$CO_{2t} = \alpha_3 + \beta_6 GDP_t + \beta_7 (GDP^2)_t + \beta_8 (GDP^3)_t + \beta_9 FDI_t + e_{t3} \qquad \ldots(3)$$

where

α_3	=	intercept (initial level of aggregate CO_2 emissions)
β_6, β_7 and β_8	=	indicators for testing the existence of a cubic form of the relationship between aggregate CO_2 emissions and GDP, that is, a cubic EKC. The expected sign of β_6 and β_8 is positive while that of β_7 is negative. If these coefficients turn out to be significant with these expected signs, it would confirm the existence of an N-shaped shaped relationship between aggregate CO_2 emissions and GDP for India over the time period 1991 to 2014
B_9	=	indicator for testing the validity of pollution haven hypothesis. The expected sign of this coefficient is positive. If it were significant with the expected sign, it would be a confirmation of the pollution haven hypothesis for India during the period 1991 to 2014

B. With per capita carbon dioxide emissions (CO_2PC) (in metric tons) as the dependent variable

B.1. Quadratic EKCPC

Functional form: $CO_2PC_t = f(GDPC_t, GDPC_t^2)$

Estimating equation

$$CO_2PC_t = \alpha_4 + \beta_{10} GDPC_t + \beta_{11} (GDPC^2)_t + e_{t4} \qquad \ldots(4)$$

where

α_4	=	intercept (initial level of per capita CO_2 emissions)
β_{10} and β_{11}	=	indicators for testing the existence of a quadratic EKCPC with per capita CO_2 emissions (CO_2PC_t) and per capita GDP ($GDPC_t$). The expected sign of β_{10} is positive while that of β_{11} is negative. If these coefficients turn out to be significant with these expected signs, it would confirm the existence of an inverted-U shaped relationship between per capita CO_2 emissions and per capita GDP for India over the time period 1991 to 2014

B.2. Cubic EKCPC

Functional form: $CO_2PC_t = f(GDPC_t, GDPC_t^2, GDPC_t^3)$

Estimating equation

$$CO_2PC_t = \alpha_5 + \beta_{12} GDPC_t + \beta_{13} (GDPC^2)_t + \beta_{14} (GDPC^3)_t + e_{t5} \quad \ldots(5)$$

where

α_5 = intercept (initial level of per capita CO_2 emissions)

β_{12}, β_{13} and β_{14} = indicators for testing the existence of a cubic EKCPC with per capita CO_2 emissions and per capita GDP. The expected sign of β_{12} and β_{14} is positive while that of β_{13} is negative. If these coefficients turn out to be significant with these expected signs, it would confirm the existence of an N-shaped shaped relationship between per capita CO_2 emissions and per capita GDP for India over the time period 1991 to 2014

B.3. Cubic EKCPC with FDI

Functional form: $CO_2PC_t = f(GDPC_t, GDPC_t^2, GDPC_t^3, FDI_t)$

Estimating equation

$$CO_2PC_t = \alpha_6 + \beta_{15} GDPC_t + \beta_{16} (GDPC^2)_t + \beta_{17} (GDPC^3)_t + \beta_{18} FDI_t + e_{t6} \quad \ldots(6)$$

where

α_6 = intercept (initial level of per capita CO_2 emissions)

β_{15}, β_{16} and β_{17} = indicators for testing the existence of a cubic form of the relationship between per capita CO_2 emissions and per capita GDP, that is, a cubic EKCPC. The expected sign of β_{15} and β_{17} is positive while that of β_{16} is negative. If these coefficients turn out to be significant with these expected signs, it would confirm the existence of an N-shaped shaped relationship between per capita CO_2 emissions and per capita GDP for India over the time period 1991 to 2014

B_{18} = indicator for testing the validity of pollution haven hypothesis. The expected sign of this coefficient is positive. If it were significant with the expected sign, it would be a confirmation of the pollution haven hypothesis for India during the period 1991 to 2014

In this context, we formulated the following **secondary hypotheses**:

1) $H_0: \beta_1 = 0$
   $H_1: \beta_1 > 0$
2) $H_0: \beta_2 = 0$
   $H_1: \beta_2 < 0$

where β_1 and β_2 are indicators for testing the existence of a quadratic EKC relationship for aggregate CO_2 emissions during 1991 to 2014

3) $H_0: \beta_3 = 0$
   $H_1: \beta_3 > 0$
4) $H_0: \beta_4 = 0$
   $H_1: \beta_4 < 0$
5) $H_0: \beta_5 = 0$
   $H_1: \beta_5 > 0$

where β_3, β_4 and β_5 are indicators for testing the existence of a cubic EKC relationship for aggregate CO_2 emissions during 1991 to 2014

6) $H_0: \beta_6 = 0$
$H_1: \beta_6 > 0$
7) $H_0: \beta_7 = 0$
$H_1: \beta_7 < 0$
8) $H_0: \beta_8 = 0$
$H_1: \beta_8 > 0$

where β_6, β_7 and β_8 are indicators for testing the existence of a cubic EKC relationship for aggregate CO_2 emissions during 1991 to 2014

9) $H_0: \beta_9 = 0$
$H_1: \beta_9 > 0$

where β_9 is an indicator for testing the validity of PHH (with aggregate CO_2 emissions as the dependent variable) for India during 1991 to 2014

10) $H_0: \beta_{10} = 0$
$H_1: \beta_{10} > 0$
11) $H_0: \beta_{11} = 0$
$H_1: \beta_{11} < 0$

where β_{10} and β_{11} are indicators for testing the existence of a quadratic EKC for per capita CO_2 emissions during 1991 to 2014

12) $H_0: \beta_{12} = 0$
$H_1: \beta_{12} > 0$
13) $H_0: \beta_{13} = 0$
$H_1: \beta_{13} < 0$
14) $H_0: \beta_{14} = 0$
$H_1: \beta_{14} > 0$

where β_{12}, β_{13} and β_{14} are indicators for testing the existence of a cubic EKC relationship for per capita CO_2 emissions during 1991 to 2014

15) $H_0: \beta_{15} = 0$
$H_1: \beta_{15} > 0$
16) $H_0: \beta_{16} = 0$
$H_1: \beta_{16} < 0$
17) $H_0: \beta_{17} = 0$
$H_1: \beta_{17} > 0$

where β_{15}, β_{16} and β_{17} are indicators for testing the existence of a cubic EKC relationship for per capita CO_2 emissions during 1991 to 2014

18) $H_0: \beta_{18} = 0$
$H_1: \beta_{18} > 0$

where β_{18} is an indicator for testing the validity of PHH (with per capita CO_2 emissions as the dependent variable) for India during 1991 to 2014

5. ANALYSIS AND RESULTS

The results obtained for each model specification are presented below:

A. With aggregate carbon dioxide emissions (CO_2) (in kilotons) as the dependent variable

A.1. Quadratic EKC

Table 2. Summary output for Quadratic EKC

Regression statistics

Multiple R	0.98842
R Square	0.97699
Adjusted R Square	0.97479
Standard Error	72497.13893
Observations	24

	Coefficients	Standard Error	t Stat	P-value
Intercept	447761.9	56894.29	7.87006	1.0697E-07
GDP	1.51E-06	1.39E-07	10.87174	4.3968E-10
GDP^2	-3.5E-19	6.23E-20	-5.65448	1.3012E-05

The R-square is 0.976, which indicates that our regression line is a good fit of the data.

Estimated equation

$$CO_{2t} = 447761.9 + 1.51E\text{-}06\, GDP_t - 3.5E\text{-}19\, (GDP^2)_t + e_{t1} \qquad \ldots(7)$$

(p-value) (1.0697E-07) (4.3968E-10) (1.3012E-05)

The estimated equation shows that the initial level of CO_2 emissions is 447761.9 kilotons. The t-statistic (7.870068) and the p-value (1.0697E-07) show that the intercept is highly significant. The coefficient of GDP (1.51E-06) is rather small; however the t-statistic (10.87174) and the p-value (4.3968E-10) show that it is highly significant. The quadratic GDP variable also has an extremely small coefficient (3.5E-19) but it is highly significant on account of the t-statistic (-5.65448) and p-value (1.3012E-05). The important thing to note is that there is the typical alternation of signs. The linear term has a positive sign while the quadratic term has a negative sign. This is indicative of a bell-shaped curve where initially aggregate CO_2 emissions rise with respect to GDP and later fall with respect to $(GDP)^2$. Therefore, we reject our null hypothesis for β_1 and β_2.

Further, from Figure 3 below, it can be inferred that although aggregate CO_2 emissions do not show a smooth quadratic pattern, in the year 2012 there is a small dip in the level of emissions. Subsequently, since the emissions rise once again, this is an indication of the presence of a cubic form.

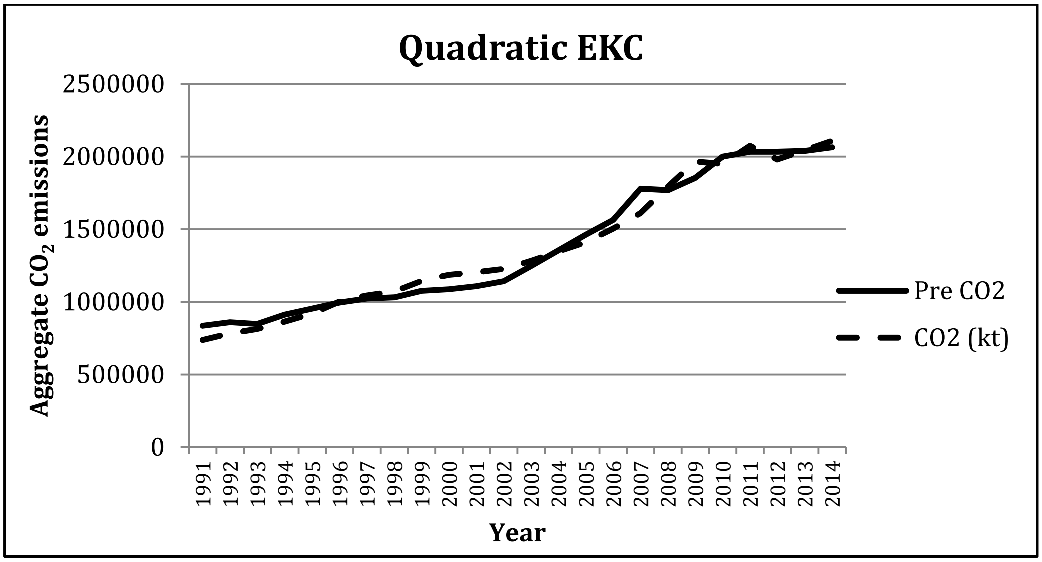

Figure 3. Quadratic EKC

A.2. Cubic EKC

Table 3. Summary output for Cubic EKC

Regression statistics

Multiple R	0.99045
R Square	0.98100
Adjusted R Square	0.97815
Standard Error	67500.27777
Observations	24

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	241680.3	113401.7	2.13118	0.04566
GDP	2.34E-06	4.25E-07	5.51241	2.14E-05
GDP^2	-1.2E-18	4.32E-19	-2.85157	0.00986
GDP^3	2.64E-31	1.28E-31	2.05529	0.05314

The cubic equation has a slightly higher coefficient of determination (0.981) as compared to the quadratic equation (0.976). This shows that the cubic equation is a better fit.

Estimated equation

CO_{2t} = 241680.3 + 2.34E-06 GDP_t - 1.2E-18 $(GDP^2)_t$ + 2.64E-31 $(GDP^3)_t$ + e_{t2} ..(8)
(p-value) (0.0456) (2.14E-05) (0.0098) (0.0531)

The intercept term is also smaller (241680.3) which shows that the cubic equation accounts for more of the explained variation. This also indicates that the cubic form of relationship between aggregate CO_2 emissions and GDP is more appropriate as compared to a quadratic form of relationship between the two variables. In other words, the influence of the cubic term was perhaps being merged in the intercept of the quadratic equation as an omitted variable. Moreover, although the coefficient of GDP in the cubic equation is very small (2.34E-06), it is highly significant as indicated by the p-value (2.14E-05). But when we compare the quadratic

and the cubic form of equation, the linear term's coefficient in the quadratic equation (1.51E-06) is two-thirds of the linear term's coefficient in the cubic equation (2.34E-06).
Further, both the quadratic terms are extremely small, yet they are significant in both the equations. However, the coefficient of the quadratic term in the cubic equation (-1.2E-18) is about three times the coefficient of the quadratic term in the quadratic equation (-3.5E-19). The implication is that the quadratic term in the cubic equation makes emissions fall faster because it bears a negative sign. In addition to this, the cubic term also has a small (2.64E-31) but significant (0.0531) influence that forces the emissions to rise again.
On the whole, we reject our null hypothesis for β_3, β_4 and β_5. This renders evidence for an N-shaped EKC for India during 1991-2014.

Moreover, from Figure 4 below, it can be inferred that the apparent pattern of a cubic EKC is not very different from the quadratic EKC. However, a closer look shows that the predicted CO_2 is closely hugging the actual in the cubic form. It also confirms that 2011 is the peak before which there is a dip in 2012, similar to the quadratic form. On the whole, this confirms the N-shaped EKC as purported in recent literature.

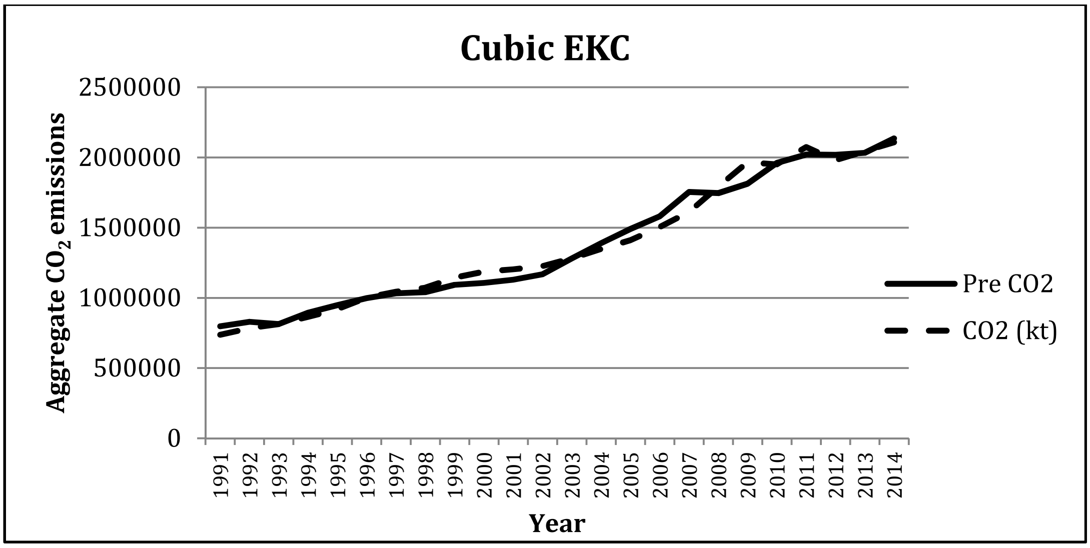

Figure 4. Cubic EKC

A.3. Cubic EKC with FDI

Table 4. Summary output for Cubic EKC with FDI

Regression statistics

Multiple R	0.99194
R Square	0.98395
Adjusted R Square	0.98057
Standard Error	63657.02
Observations	24

	Coefficients	Standard Error	t Stat	P-value
Intercept	240942.2	106945.7	2.25294	0.03627
GDP	2.41E-06	4.03E-07	5.99413	9.09E-06
GDP^2	-1.5E-18	4.32E-19	-3.47178	0.00255
GDP^3	3.63E-31	1.32E-31	2.74558	0.01285
FDI	4.87E-06	2.61E-06	1.86758	0.07732

The R-square is very high (0.983), which again indicates that the fit is very good.

Estimated equation

CO_{2t} = 240942.2 + 2.41E-06 GDP_t - 1.5E-18 $(GDP^2)_t$ + 3.63E-31 $(GDP^3)_t$ + 4.87E-06 FDI_t + e_{t3} ..(9)
(p-value) (0.0362) (9.09E-06) (0.0025) (0.0128) (0.0773)

The intercept (240942.2) is significant because the p-value is 0.0362. Once again it is noticed that the intercept in this equation (240942.2) almost halves in comparison to the intercept in the quadratic EKC equation (447761.9). The implication is that the cubic GDP and the FDI variable add to the explanatory power and take away from the unaccounted or omitted variables. Although FDI has a very small coefficient (4.87E-06), it is significant at 10% level (0.0773). Hence, we reject our null hypothesis for β_9 and validate the PHH for India during 1991-2014. The other coefficients, that is, the linear (2.41E-06), quadratic (-1.5E-18) and cubic (3.63E-31) terms are all small but highly significant (9.09E-06, 0.0025 and 0.0128 respectively). Also each of these terms bears the right sign, that is, the linear and the cubic terms are positive while the quadratic term is negative. Hence, we reject our null hypothesis for β_6, β_7 and β_8 and validate a cubic EKC for India.

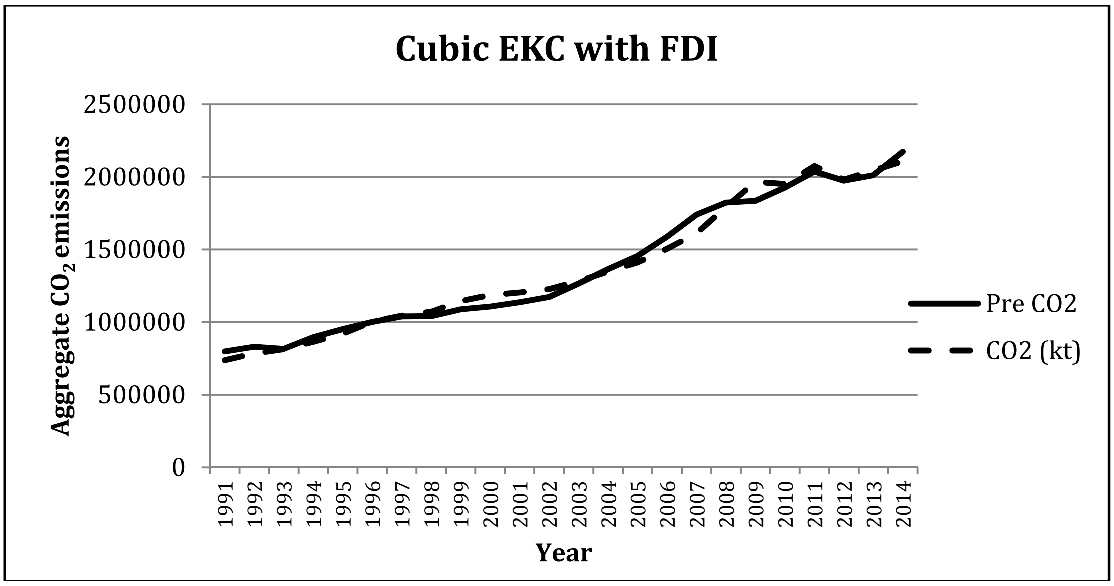

Figure 5. Cubic EKC with FDI

As has been observed in the earlier formulations, in Figure 5 also the downturn occurs after 2011. In addition, the two curves, actual CO_2 and predicted CO_2, do display a fair amount of cohesion.

B. With per capita carbon dioxide emissions (CO_2PC) (in metric tons) as the dependent variable

B.1. Quadratic EKCPC

Table 5. Summary output for Quadratic EKCPC

Regression statistics

Multiple R	0.98255
R Square	0.96542
Adjusted R Square	0.96212
Standard Error	0.05467
Observations	24

	Coefficients	Standard Error	t Stat	P-value
Intercept	0.54828	0.05963	9.19433	8.25783E-09
GDPC	0.00127	0.00016	7.66319	1.62971E-07
$GDPC^2$	-3.6E-07	9.03E-08	-3.99877	0.00065

The R-square is 0.965, which indicates that the regression line is a good fit.

Estimated equation

$$CO_2PC_t = 0.548287 + 0.001271\, GDPC_t - 3.6E\text{-}07\, (GDPC^2)_t + e_{t4} \quad \ldots(10)$$

(p-value) (8.25783E-09) (1.62971E-07) (0.0006)

Now, we consider the quadratic equation with per capita CO_2 emissions as the dependent variable. Once again, we first consider the intercept whose value is 0.54828 metric tons, which is statistically significant (8.25783E-09). This indicates the initial level of per capita emissions. It also implies that two-thirds of the initial emissions (0.83043 in 1991) form the intercept (0.54828), while the intercept as a proportion of the final per capita emissions (1.67872 in 2014) is 0.32660. The situation has reversed because initially two-thirds were being contributed by the intercept, whereas now, the same is contributing only one-third. Thus, overtime there have been other determinants, which have aggravated the per capita emissions.

The other factor in this case is clearly identified as GDP. Over the 24-year period (1991 to 2014), GDP has acted as a proxy for economic development. Thus, the quadratic per capita emissions pattern is maintained wherein both the linear per capita GDP term (0.0012) and the quadratic per capita GDP term (-3.6E-07) are statistically significant (1.62971E-07 and 0.0006 respectively). These terms also bear the correct signs such that the linear term is positive while the quadratic term is negative. Consequently, we reject our null hypotheses for β_{10} and β_{11}.

Figure 6 below, shows that the patterns observable in the per capita emissions are quite similar to what were observed for aggregate emissions. The timing of the downturn is also parallel to what was observed for aggregate emissions. The turning point is the same and the impact is also temporary. The small dip that happens around 2012 gets converted into a rising trend very soon. Hence, both the aggregate emissions as well as per capita emissions point towards the need for implementing a cubic equation.

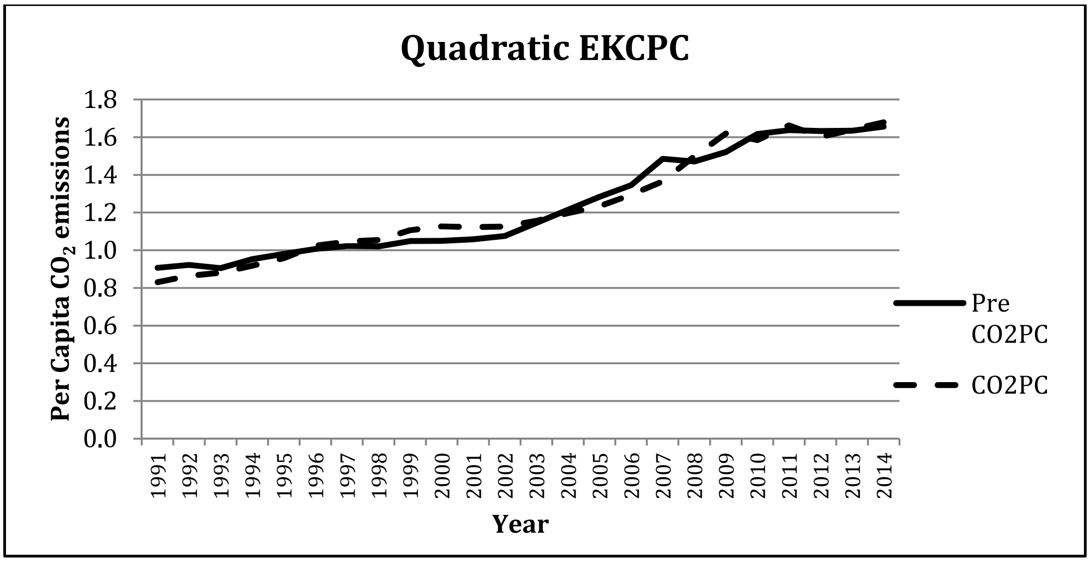

Figure 6. Quadratic EKCPC

B.2. Cubic EKCPC

Table 6. Summary output for Cubic EKCPC
Regression statistics

Multiple R	0.98455
R Square	0.96935
Adjusted R Square	0.96475
Standard Error	0.05274
Observations	24

	Coefficients	Standard Error	t Stat	P-value
Intercept	0.32681	0.14980	2.18163	0.04124
GDPC	0.00223	0.00062	3.58067	0.00187
$GDPC^2$	-1.56E-06	7.5354E-07	-2.06959	0.05165
$GDPC^3$	4.3688E-10	2.7285E-10	1.60117	0.12501

The R-square is 0.969, which indicates that the regression is a good fit.

Estimated equation

CO_2PC_t = 0.32681 + 0.00223 $GDPC_t$ -1.56E-06 $(GDPC^2)_t$ + 4.3688E-10$(GDPC^3)_t$ + e_{t5} ...(11)
(p-value) (0.0412) (0.0018) (0.0516) (0.1250)

A similar cubic equation is constructed for per capita emissions as was constructed for the aggregate emissions. Here, the intercept is smaller (0.32681) than that of the quadratic EKC per capita (0.54828). It reflects the same phenomenon of the cubic term being absorbed in the intercept in the quadratic equation. Moreover, the linear terms in both the equations are not very further apart (0.00127 in Quadratic EKCPC and 0.00223 in Cubic EKCPC). However, the coefficient of the quadratic term in the cubic equation (-1.56E-06) is around 2.5 times the coefficient of the quadratic term in the quadratic equation (-3.6E-07). This also shows that the cubic function is a better fit because it explains the variation better. Finally, the cubic term

(4.3688E-10) in this case bears the right sign (positive) but the p-value is 0.1250, which means that the evidence on relinking hypothesis in per capita terms is weak. Nevertheless, we reject our null hypothesis for β_{12}, β_{13} and β_{14}. However, weak evidence on the cubic term points towards the difference in the socio-psychological factors that influence the revival of the upturn in the case of India. In other words, India might not necessarily behave like the developed countries at later stages of development, unlike the implicit EKC assumption of common developmental patterns of nations.

Moreover, since the cubic term is not so significant, the predicted CO_2 per capita does not perfectly match the actual CO_2 per capita in Figure 7 below. The point of downturn however, is the same as for the equations previously discussed.

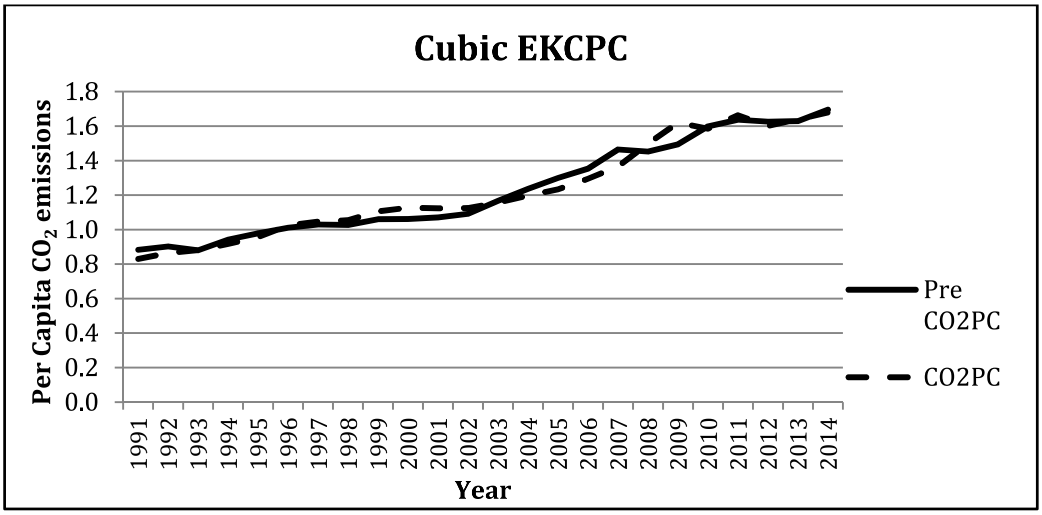

Figure 7. Cubic EKCPC

B.3. Cubic EKCPC with FDI

Table 7. Summary output for Cubic EKCPC with FDI

Regression statistics

Multiple R	0.98796
R Square	0.97608
Adjusted R Square	0.97104
Standard Error	0.04780
Observations	24

	Coefficients	Standard Error	t Stat	P-value
Intercept	0.28907	0.13674	2.11392	0.04797
GDPC	0.00253	0.00058	4.36096	0.00033
$GDPC^2$	-2.2E-06	7.41E-07	-3.00031	0.00735
$GDPC^3$	7.17E-10	2.75E-10	2.60325	0.01746
FDI	4.65E-12	2.01E-12	2.31272	0.03210

The R-square is 0.976, which indicates the goodness of fit of the regression line.

Estimated equation

$CO_2PC_t = 0.28907 + 0.00253\ GDPC_t - 2.2E\text{-}06(GDPC^2)_t + 7.17E\text{-}10(GDPC^3)_t + 4.65E\text{-}12\ FDI_t + e_{t6}$ …(12)

(p-value) (0.0479) (0.0003) (0.0073) (0.0174) (0.0321)

We now estimate a cubic form of equation on the basis of per capita emissions and per capita GDP. Once again, all the coefficients are significant at 5% level and bear the right signs such that the linear and cubic GDP terms are positive while the quadratic GDP term is negative. The intercept is 0.28907 with a p-value of 0.0479. The linear, quadratic and cubic GDP terms are 0.00253, -2.2E-06 and 7.17E-10 respectively with 0.0003, 0.0073 and 0.0174 as their respective p-values. We therefore, reject our null hypothesis for β_{15}, β_{16} and $\beta_{17.}$ This confirms an N-shaped EKC in terms of per capita emissions. Also, the FDI coefficient is 4.65E-12 with a p-value of 0.0321, which makes us reject our null hypothesis for β_{18}. Hence in this case, both the relinking hypothesis and the pollution haven hypothesis show more robust results.

As between the two equations, the cubic term in the per capita form is 7.17E-10 whereas the cubic term in the aggregate form is 3.63E-31. Secondly, the FDI term has a p-value of 0.0773 in the aggregate form whereas in the per capita form the p-value is below 5% (0.0321). In per capita terms, it would be obvious that FDI is likely to have a smaller influence, which can be gauged from the respective coefficients, 4.87E-06 in aggregate terms and 4.65E-12 in per capita terms. This means that the pollution haven hypothesis (PHH) is not really working at the individual level. But, since FDI is more significant in per capita terms, it implies that we cannot ignore this phenomenon in spite of its impact being smaller numerically.

Also, according to Figure 8 below, the two curves, predicted CO_2 per capita and actual CO_2 per capita, lie very close to each other. Therefore, the inclusion of FDI in the per capita equation has really benefitted in terms of the goodness of fit.

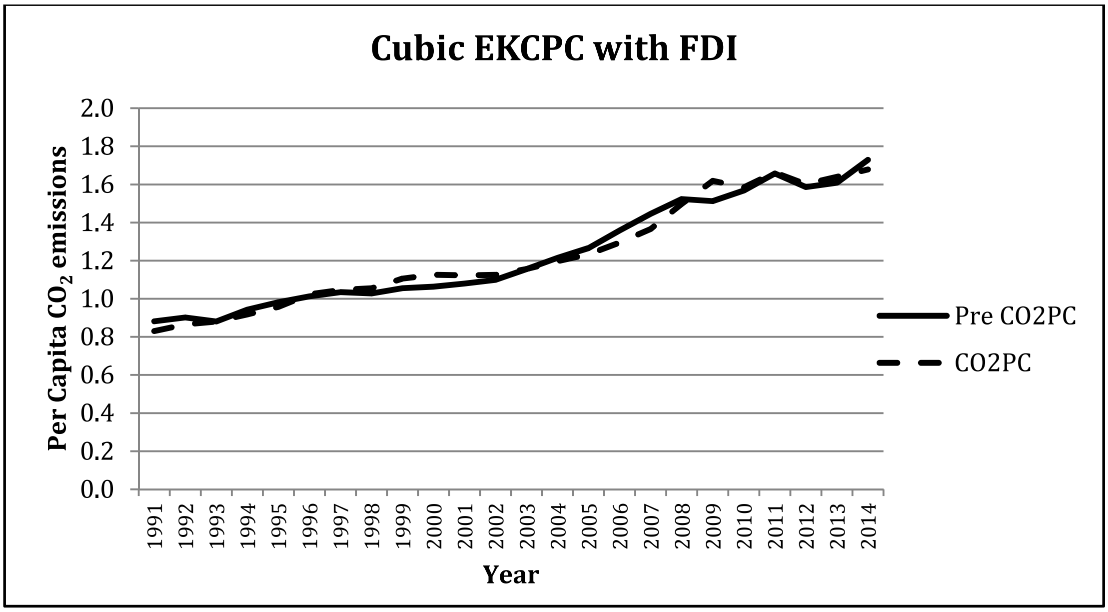

Figure 8. Cubic EKCPC with FDI

6. CONCLUSION AND POLICY RECOMMENDATIONS

The original EKC literature restricts itself to a quadratic form of the relationship between GDP and CO_2 emissions, in aggregate or per capita terms. This is on account of the delinking hypothesis. The new literature challenges this quadratic form of EKC where it is clearly established that the EKC shows up as an N-shaped curve. We have modeled the relationship between GDP and CO_2 emissions (aggregate and per capita) with alternative model specifications to bridge the gap between conventional and modern EKC studies. Our analysis of the alternative model specifications (with aggregate CO_2 emissions as the dependent variable) substantiates a cubic form of EKC in the Indian context. The linear (2.34E-06), quadratic (-1.2E-18) and cubic (2.64E-31) terms are all significant with the right signs, which confirms an N-shaped EKC as has been purported in the recent literature. Moreover, when we add the FDI variable to the model of cubic EKC, we find that FDI has a small but positive and significant coefficient (at 10 % level). Hence, we validate PHH for India in our model integrating EKC and PHH.

Even with per capita emissions as the dependent variable, the N-shaped EKC is established. But, in this case, evidence on the cubic term is rather weak (p-value = 0.1250), which points towards the difference in the socio-psychological factors that influence the revival of the upturn in the case of India. Also, FDI has a smaller influence in per capita terms, which could be gauged from the respective coefficients, in aggregate and per capita equations. This implies that PHH is not really working at the individual level. However, FDI is more significant in per capita terms, which means that we cannot ignore this phenomenon yet numerically its impact is much smaller.

On the whole, our study substantiates that a cubic form of relationship between aggregate CO_2 emissions and GDP is more appropriate as compared to a quadratic form of relationship between the two variables. In other words, India exhibits an N-shaped EKC pattern during 1991 to 2014, which implies that at relatively higher levels of income, the benefit from cleaner technologies is outweighed by the degradation caused due to excessive consumption. We also validate PHH in the Indian context through our model synthesizing EKC and PHH, both in aggregate and per capita terms. Hence, we reject both our primary hypotheses that there is not enough evidence to validate EKC in the Indian context and that there is not enough evidence to validate PHH in the Indian context. Also the non-existence of a joint EKC-PHH hypothesis in India is rejected. These findings are in accordance with the new literature, which is the basis of the trade, environment and economic development triangle.

The policy recommendation, therefore, is that both policy makers and literature needs to recognize that in the Indian context the re-linking hypothesis exists. The policy implication is that gains of green technologies are being wiped out by over-consumption of environmentally unfriendly goods. India may be falling into the trap that developed economies already experienced (the *N*-shaped EKC). In terms of PHH the policy recommendation is clear that indiscriminate introduction and encouragement of FDI that raises the level of pollution is not welcome in India. She needs to evolve screening procedures and active research to identify such foreign investment that does not dump polluting technologies in India. Moreover, over consumption needs to be curbed. Especially, conspicuous consumption of environmentally unfriendly goods and bad practices need to be checked.

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