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SURVEY

Environmental Kuznets Curve Hypothesis: A Survey

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Abstract

The *Environmental Kuznets Curve* (*EKC*) hypothesis postulates an inverted-U-shaped relationship between different pollutants and per capita income, i.e., environmental pressure increases up to a certain level as income goes up; after that, it decreases. An EKC actually reveals how a technically specified measurement of environmental quality changes as the fortunes of a country change. A sizeable literature on EKC has grown in recent period. The common point of all the studies is the assertion that the environmental quality deteriorates at the early stages of economic development/growth and subsequently improves at the later stages. In other words, environmental pressure increases faster than income at early stages of development and slows down relative to GDP growth at higher income levels. This paper reviews some theoretical developments and empirical studies dealing with EKC phenomenon. Possible explanations for this EKC are seen in (i) the progress of economic development, from clean agrarian economy to polluting industrial economy to clean service economy; (ii) tendency of people with higher income having higher preference for environmental quality, etc. Evidence of the existence of the EKC has been questioned from several corners. Only some air quality indicators, especially local pollutants, show the evidence of an EKC. However, an EKC is empirically observed, till there is no agreement in the literature on the income level at which environmental degradation starts declining. This paper provides an overview of the EKC literature, background history, conceptual insights, policy and the conceptual and methodological critique.

Keywords: Economic growth; Environmental Kuznets Curve; EKC; Environmental quality; Environmental protection; Pollution; Turning point; Inverted-U-shape

JEL classification: N50; O13; Q20

1. Introduction

Worldwide deterioration of environmental quality has made many feel concerned about the issue and mounting public concern over environmental issues has sparked efforts to understand more clearly the reasons for environmental degradation. The environmental effects of economic growth have been receiv-

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ing increasing attention of economists in recent years. One particular aspect, the linkage of environment with economic growth/development, evoked much discussion in the last decade (i.e., 1990s) and a sizeable literature on the pollution–income growth relationship has grown in recent period. The common point of all the studies is the assertion that environmental quality deteriorates in early stage of economic development/growth and improves in later stage as an economy develops. In other words, environmental pressure increases faster than income in the early stage of development and slows down relative to GDP growth in higher income levels. This systematic relationship between income change and environmental quality has been called the *Environmental Kuznets Curve* (*EKC*). The inverted-U relationship derives its name from the work of Kuznets (1955) who postulated a similar relationship between income inequality and economic development. The logic of EKC relation is intuitively appealing. In the first stage of industrialization, pollution grows rapidly because high priority is given to increase material output, and people are more interested in jobs and income than clean air and water (Dasgupta et al., 2002). The rapid growth inevitably results in greater use of natural resources and emission of pollutants, which in turn put more pressure on environment. People are too poor to pay for abatement, and/or disregard environmental consequences of growth. In later stage of industrialization, as income rises, people value the environment more, regulatory institutions become more effective and pollution level declines. Thus, EKC hypothesis posits a well-defined relationship between level of economic activity and environmental pressure (defined as the level of concentration of pollution or flow of emissions, depletion of resources, etc.). An Environmental Kuznets Curve reveals how a technically specified measurement of environmental quality changes as the fortunes of a country or a large human community change. In brief, Environmental Kuznets Curves are statistical artifacts that summarize a few important aspects of collective human behaviour in two-dimensional space. The EKC hypothesizes an inverted-U-shaped curve when pollution indicators are plotted against income per capita.

The EKC results have shown that economic growth could be compatible with environmental improvement if appropriate policies are taken. It is a significant condition that only when income grows, the effective environmental policies can be implemented.[1] Clearly, before adopting a policy, it is important to understand the nature and causal relationship between economic growth and environmental quality (Coondoo and Dinda, 2002). Therefore the relevant question is: Can economic growth be part of the solution rather than the cause of environmental problem? This has been the primary motivation for empirical studies on EKC searching for evidence of link between income and environmental degradation. It has provoked a vast empirical research over the last decade (i.e., 1990s). The 1990s have seen the advent of EKC hypothesis and an explosion of studies that tested it for several pollutants. The aim of the present paper is not to go further on these issues, but to visualize the current state of knowledge about the EKC. Stern (1998), Ekins (1997), de Bruyn and Heintz (1998) and Stagl (1999) provide good overviews and comparisons. This *EKC-Review* is slightly different from earlier reviews and here the literature added since then is taken into consideration.

The second section of this paper provides the background history of the environment–economic growth debate and genesis of the EKC; the third section provides a general idea and some conceptual insights and the fourth section deals with theoretical reviews. Empirical evidences have been reviewed in the fifth section, policy implication in the sixth section, and a conceptual and methodological critique has been presented in the seventh section. Finally, the paper concludes with some remarks for direction of future research.

2. Background history of EKC

2.1. Growth controversy

The origin of the EKC debate is the growth controversy and related policies. Researchers hypothesize that a higher level of income increases environmental degradation. Actually, higher levels of income may reduce environmental degradation (Beckerman,

[1] This line of thinking was present in the World Development Report-1992 of the World Bank.

1992), and thus, economic growth may be a precondition for environmental improvement (Bhagawati, 1993). So, growth could be a powerful way for improving environmental quality in developing countries (Panayotou, 1993). The argument according to which economic growth is ultimately beneficial for environment is, however, controversial[2] since it prompts the idea of a development path,[3] a stage-based link between environmental quality and economic growth.

Truly, the relationship between economic growth and environmental quality has been an object of a long debate for many years. Before 1970, there was a belief that the consumption of raw materials, energy and natural resources grow almost at the same rate (viz., steady state) as economy grows. In the early 1970s, the Club of Rome's *Limits to Growth* view (Meadows et al., 1972) was forwarded about the concern for availability of natural resource of the Earth. The environmental economists of the Club of Rome argued that the finiteness of environmental resources would prevent economic growth and urged for a steady-state economy with zero growth to avoid dramatic ecological scenarios in the future. This view has been criticized on both theoretical and empirical grounds. Empirical works show that the ratio of consumption of some metals to income was declining in developed economies during the 1970s, which conflicts with the predictions set out in the Limits to Growth view (Malenbaum, 1978). This view induced to examine the relationship between the intensity of metal use and income, and an inverted-U curve was found. This inverted-U curve (known as *intensity-of-use hypothesis* (Auty, 1985)) reveals that intensity of materials-use[4] decreases beyond a threshold level of income (Canas et al., 2003, de Bruyn and Heintz, 1998).

From the beginning of the 1990s, empirical data on various pollutants become available through the Global Environmental Monitoring System (GEMS), the environmental data compendium of the OECD, the CO_2 emission estimates from the Oak Ridge National Laboratory (ORNL), etc. These data availability induce several authors to test the validity of the inverted-U curve hypothesis for income and environmental quality indicators. The first empirical study appears in the NBER working paper by Grossman and Krueger (1991); after that, a number of studies follow.

2.2. Genesis of EKC

Kuznets (1955) predicted that the changing relationship between per capita income and income inequality is an inverted-U-shaped curve. As per capita income increases, income inequality also increases at first and then starts declining after a turning point (TP). In other words, the distribution of income becomes more unequal in early stage of income growth and then the distribution moves towards greater equality as economic growth continues (Kuznets, 1955). This relationship between income per capita and income inequality can be represented by a bell-shaped curve. This observed empirical phenomenon is popularly known as the Kuznets Curve.

In the 1990s and onwards, the Kuznets Curve took on a new existence. There is evidence that the level of environmental degradation and per capita income follows the same inverted-U-shaped relationship as does income inequality and per capita income in the original Kuznets Curve. Now, Kuznets Curve has become a vehicle for describing the relationship between measured levels of environmental quality (for example, concentration of SO_2) and per capita income. This inverted-U-shaped relationship between economic growth and measured pollution indicators (environmental quality) is known as the EKC.

First set of empirical EKC studies appeared independently in three working papers: an NBER working paper as part of a study of the environmental impacts of NAFTA (Grossman and Krueger, 1991), the World Bank's 1992 World Development Report (Shafik and Bandyopadhyay, 1992) and a Development Discussion paper as part of a study for the International Labour Organisation (Panayotou, 1993). Grossman and Krueger (1991) in an NBER working paper, which was later published in 1993 (Grossman and Krueger, 1993), first pointed out an inverted-U relationship

[2] Existing environmental regulation, by reducing economic growth, may actually be reducing environmental quality (Bartlett, 1994).

[3] In recent time, this link raises the issue of potential conflicts between the globalization and protection of the environment.

[4] Other studies have found a general tendency of an absolute decline in consumption of several materials after 1973, and it is mostly pronounced in developed economies (Williams et al., 1987; Tilton, 1990).

between pollutants (SO_2 and smoke) and income per capita. Kuznets' name was attached to the inverted-U relationship between pollution and economic development later due to its resemblance to Kuznets' inverted-U relationship between income inequality and economic development. However, Panayotou (1993) first coined it as the Environmental Kuznets Curve or EKC.

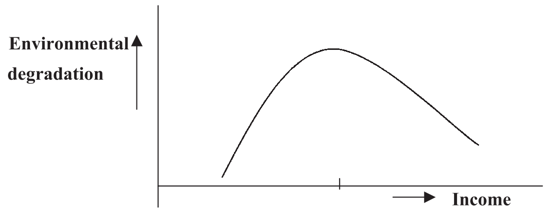

Fig. 1. Environmental Kuznets Curve.

3. Conceptual background of EKC

3.1. General idea

Corresponding to the early stage of economic growth,[5] the awareness of environmental problems is low or negligible and environment friendly technologies are not available.

Environmental degradation increases with growing income up to a threshold level beyond which environmental quality improves with higher income per capita. This relationship can be shown by an inverted-U-shaped curve (see Fig. 1). It is described as the EKC following the observation of Kuznets (1955). This EKC hypothesis is intended to represent a long-term relationship between environmental impact and economic growth. As economic development accelerates with the intensification of agriculture and other resource extraction, at the take-off stage, the rate of resource depletion begins to exceed the rate of resource regeneration, and waste generation increases in quantity and toxicity. At higher levels of development, structural change towards information-intensive industries and services, coupled with increased environmental awareness, enforcement of environmental regulations, better technology and higher environmental expenditures, results in leveling off and gradual decline of environmental degradation. As income moves beyond the EKC turning point, it is assumed that transition to improving environmental quality starts. Thus, it could be a depiction of the natural process of economic development from a clean agrarian economy to a polluting industrial economy, and, finally, to a clean service economy (Arrow et al., 1995).

3.2. Explanations for the EKC

The EKC hypothesis actually summarizes an essentially dynamic process of change—viz., as income of an economy grows over time, emission level grows first, reaches a peak and then starts declining after a threshold level of income has been crossed. However, the statement of the hypothesis makes no explicit reference to time. Truly, the EKC is a long run phenomenon. In other words, it is a development trajectory for a single economy that grows through different stages over time. That is, *ceteris paribus*, in their process of development, individual countries experience income and emission situations lying on one and the same EKC. Empirically, this development trajectory can be observed in cross-country cross-sectional data, which represents the countries with different (low, middle and high) income groups (of the world) corresponding to their emission levels. Assuming all countries follow one EKC, then at any cross-section of time, it should be observed that some countries are poor shaping the initial stage of EKC, some are developing countries approaching towards peak or start to decline and other are rich produce falling stage of EKC. Evidently, thus, under the null hypothesis of EKC and under the assumption of invariance of the income–emission relationship, for a given set of cross-country cross-sectional data on income and emission, the emission on income regression line should be an inverted-U-shaped empirical EKC.

Several factors are responsible to shape the EKC. Considering other things remain constant, i.e., *ceteris*

[5] A growing economy has positive social and economic effects. It is true that economic activities are presupposed a function of the environment. But a few are conscious about the effects of economic growth on environmental quality. However, the effect of economic growth on environmental quality is much under dispute. At the beginning of development trajectory a country's GDP increases corresponding with high environmental degradation.

paribus, each factor is analyzed in the following subsections one by one to explain the EKC.

3.2.1. Income elasticity of environmental quality demand

As income grows, people achieve a higher standard of living and care more for the quality of environment they live in and demand for better environment induces structural changes in economy that tends to reduce environmental degradation. The most common explanation for the shape of an EKC is the notion that when a country achieves a sufficiently high standard of living, people attach increasing value to environmental amenities (Pezzey, 1989; Selden and Song, 1994; Baldwin, 1995). After a particular level of income, the willingness to pay for a clean environment rises by a greater proportion than income (Roca, 2003). This will be reflected through defensive expenditures, donations to environmental organizations or choice of less environmentally damaging products. Thus, rich people value the clean environment and preserve it. Generally, it is recognized that income elasticity of environmental quality demand and resource goods is in excess of unity, i.e., clean environment and preservation are ‘luxury goods’. But major indicators of environmental degradation are monotonically rising in income though the income elasticity is less than one and is not a simple function of income alone. However, most of the EKC models have emphasized the role of income elasticity[6] of environmental quality demand (Beckerman, 1992; Carson et al., 1997; Chaudhuri and Pfaff, 1998; McConnell, 1997) and this elasticity is often invoked in the literature as the main reason to explain the reduction of emission level. An adequate explanation of observed EKC relationships for some pollutants'[7] are consistent with the high-income elasticity of environmental quality demand (McConnell, 1997; Shafik, 1994). Poor people have little demand for environmental quality, however, as a society becomes richer, its members may intensify their demands for a more healthy and cleaner environment. The consumers with higher incomes are not only willing to spend more for green products but also create pressure for environmental protection and regulations. In most cases where emissions have declined with rising income, the reductions have been due to local and national institutional reforms, such as environmental legislation and market-based incentives to reduce environmental degradation.

3.2.2. Scale, technological and composition effects

Economic growth affects the quality of environment in three different channels—viz., *scale effects*, *technological effects* and *composition effects* (Grossman and Krueger, 1991). Increasing output requires more input and thus more natural resources are used up in production process. More output also implies more wastes and emissions as by-product, which also contributes to degrade environmental quality. Economic growth, thus, exhibits a scale effect that has a negative impact on environment. However, economic growth has also a positive impact on environment through a composition effect: As income grows, structure of the economy tends to change and gradually increases cleaner activities that produce less pollution. Environmental degradation tends to increase as structure of the economy changes from rural to urban or agricultural to industrial, but it starts to fall with another structural change from energy intensive industry to services and knowledge based technology-intensive industry. As a wealthy nation can afford to spend more on R&D (Komen et al., 1997), technological progress occurs with economic growth and the dirty and obsolete technologies are replaced by upgraded new and cleaner technology, which improves environmental quality. This is the *technique effect* of economic growth. The EKC suggests that the

[6] A household-level income–environment relationship can be derived from the purchase of private goods with environmental characteristics (for example, Water-Filter Acqua-guard, Zeoline, etc., against water pollution; mask, air conditioning against air pollution, etc.). As household income rises, (s)he is expected to increase (her) his expenditure on the purchase of environmental quality enhancing goods, that means Engel Curve for such goods can be estimated. Using household-level data of Pakistan, Engel's Curve is estimated and the EKC relationship between indoor air quality and household income is found after simulation (Chaudhuri and Pfaff, 1998). Micro-data of the USA also support the existence of the EKC relationship between income and vehicle emissions at household level (Kahn, 1998).

[7] The most contingent valuation studies have found an income elasticity of demand for environmental services smaller than unity (Kristrom and Riera, 1996).

negative impact on environment of the scale effect that tends to prevail in initial stages of growth, but it will eventually be outweighed by positive impact of the composition and technique effects[8] that tend to lower the emission level (Vukina et al., 1999).

3.2.3. International trade

International trade is one of the most important factors that can explain EKC. Trade leads to increase in size of the economy that increases pollution, thus, trade is the cause of environmental degradation *ceteris paribus*. But many economists have long argued that trade is not the root cause of environmental damage (Birdsall and Wheeler, 1993; Lee and Roland-Holst, 1997; Jones and Rodolfo, 1995). However, free trade has the contradictory impacts on environment, both increasing pollution and motivating reductions in it. Environmental quality could decline through the scale effect as increasing trade volume (especially export) raises the size of economy, which increases pollution. On the other hand, trade can improve the environment through composition effect and/or technique effect (i.e., as income rises through trade, environmental regulation is tightened that spurs pollution reducing innovation). The pollution from the production of pollution-intensive good declines in one country as it increases in other country via international trade. This composition effect is attributed to two related hypotheses: *Displacement Hypothesis* and *Pollution Haven Hypothesis*. Fundamentally, these two hypotheses have no difference. These hypotheses are basically the same with respect to comparative advantage in international trade. As trade relates one country with international communities, one underdeveloped economy may rely on technology transfer through foreign direct investment (FDI) that may reduce pollution.

[8] With regard to the technique effect there are many examples of efficient resource use, substitutions between resources, and containment of wastes. The most dramatic are reduction of SO_2 in Germany, France and Japan by the installation of flue-gas desulphurization equipment (in Germany), a switch over to nuclear power (in France), and a combination of these two (in Japan). However, both alternatives have secondary environmental effects, i.e., quarrying and transport of large quantities of limestone for flue-gas desulphurization, waste disposal, radioactive emissions and risk of accidents for nuclear power. These secondary effects should always be incorporated into an environmental assessment when benefits from advances in technology are appraised.

3.2.3.1. Displacement Hypothesis. The alleged emergence of structural change in production has been linked with consumption and international trade (Arrow et al., 1995; Stern et al., 1996; Ekins, 1997; Rothman, 1998). The changes in the structure of production in developed economies are not accompanied by equivalent changes in the structure of consumption, therefore, EKC actually records displacement of dirty industries to less developed economies. Under certain circumstances, the pollution intensive industries migrate from countries with stronger environmental regulations to those with weaker regulations (Copeland and Taylor, 1995). The composition of international trade, however, actually reflects the energy consumption of a country (Agras and Chapman, 1999), and countries that export more manufactured goods tend to have a higher energy consumption (Suri and Chapman, 1998). Poor countries are likely to be net exporters and rich countries to be net importer of pollution-intensive goods (Saint-Paul, 1994). The observed inverted-U curves may be the result of changes in international specialization. That means, poor countries are concentrated in ‘dirty’ and material intensive production while richer countries specialize in ‘clean’ and service intensive production, without altering consumption patterns (Cole et al., 2000; Janicke et al., 1997; Stern et al., 1996). This is true only when environmental effects are being displaced from one country to another, rather than reduced. These observations are consistent with the Displacement Hypothesis. The Displacement Hypothesis expects that trade liberalization or openness (Harrison, 1996) will lead more rapid growth of pollution-intensive industries in less developed economies as developed economies enforce strict environmental regulations[9] (Rock, 1996; Tobey, 1990).

The composition effect and the displacement effect seem not to be independent. So far, as the composition effect is due to displacement, later developing

[9] For example, toxic intensity decreases with openness of the economy and growth rate of the toxic intensity of manufacturing increases in poor countries. Toxic intensity has grown quickly in high-income countries during the 1960s, this pattern has sharply reversed during the 1970s and 1980s, after the advent of stricter OECD environmental regulation, ...toxic intensity in LDC manufacturing has grown quickly (Hettige et al., 1992). Other studies also agree with the displacement hypothesis (Low and Yeats, 1992).

countries will not be able to derive benefit from it, for lack of other countries to which environmentally intensive activities can be displaced.

3.2.3.2. Pollution Haven Hypothesis. Free trade can be good for environment (Antweiler et al., 2001; Liddle, 2001). Trade raises income levels of people in developing countries, and by raising real incomes, it will create demands for tighter environment protection because higher income individuals want a cleaner environment. But lower trade barriers could hurt environment if heavy polluters move to countries with weaker regulations. Economists call this the Pollution Haven Hypothesis (PHH). The PHH refers to the possibility that multinational firms, particularly those engaged in highly polluting activities, relocate to countries with lower environmental standards.[10] The PHH argues that low environmental standards become a source of comparative advantage, and thus shifts in trade patterns. The PHH is basically a theory that suggests that high regulation countries will lose all the ‘dirty industries’ and poor countries will get them all.

3.2.3.3. Foreign direct investment. Developing countries can be said to provide a ‘pollution haven’ if they set environmental standards below their efficiency levels in order to attract foreign investment. Most of the developing countries rely on technology transfer through foreign direct investment from developed countries as a primary means of technology acquisition.[11] These clean and upgraded technologies will reduce pollution level. However, recent increased global eco-consciousness and linking of trade and investment with environmental issues has the potential of disrupting these investments flow.[12]

3.2.3.4. Race to bottom. In a *race to bottom* scenario, relatively high environmental standards in developed economies impose high costs on polluters. So, polluting activities in high-income economies face higher regulatory costs than their counterparts in developing countries (Jaffe et al., 1995; Mani and Wheeler, 1998). This creates an incentive for at least some highly polluting industries[13] to relocate and thereby international capital reallocations take place. Rising capital outflows force governments in high-income countries to begin relaxing environmental standards. As the race to bottom accelerates, the EKC flattens and rises toward higher existing level of pollution.

3.2.3.5. Diffusion of technology. With international trade, technological innovation is more important than in a closed market economy. Developed countries must continually innovate, not just to grow but even to maintain their real incomes.[14] Diffusion of technology prevents economic latecomers from requiring the same levels of materials and energy inputs per unit of GDP than older industrialized countries needed in past. International trade enhances diffusion of clean technology (Martin and Wheeler, 1992; Reppelin-Hill, 1999). Some authors have suggested that this might allow developing countries to ‘dive through’ the EKC.

3.2.3.6. International assistance. International communities[15] also play an important role in lowering and flattening EKC by financing for appropriate training, policy reforms, information collection and public environmental education. Their aided research programmes provide easily accessible information about polluters, pollution damages, local environmental quality, cost of pollution abatement, stronger regulatory institutions, cost-effective measures, etc., should help to reduce pollution (Dasgupta et al., 2002).

3.2.3.7. Globalization. Globalization could trigger the environmental ‘race to bottom’ (Wheeler, 2000), in which competition increases for investment and jobs. In fact, ‘the bottom’ rises with economic growth. Poor economies improve their environmental quality as investment increases income and employment. So, globalization is compatible with pollution reduction

[10] See Cole (2004), Eskeland and Harrison (2003), Friedl and Getzner (2003), Jha et al. (1999), Mani and Wheeler (1998), Ratnayake (1998), Smarzynska and Wei (2001) and Wu (2003).

[11] See Dasgupta et al. (2001a,b), Dean (2004), Dessus and Bussolo (1998), Letchumanan and Kodama (2000), Neumayer (2003), Smarzynska and Wei (2001) and Wheeler (2000).

[12] See Bommer (1999), Dean (2004), Letchumanan and Kodama (2000) and Xing and Kolstad (1995).

[13] The firms are relocated to low-income countries with weak environmental regulation.

[14] For developing countries, transfer of technology, in addition to direct benefits, brings the indirect benefit of improved terms of trade.

[15] For example, World Bank Aided India: Environment Management Capacity Building Technical Assistance Project.

(Dessus and Bussolo, 1998; Grether and Melo, 2002; Robinson, 1988). Economic globalization[16] is a driving force for global economic growth, yet, opinion is divided about the benefits of this process (Tisdell, 2001). This global, liberal, open economy raises the issue of potential conflicts between two powerful current trends—one, the worldwide acceptance of market oriented economic reform process, and another is environmental protection.

3.2.4. Market mechanism

An argument (World Bank, 1992; Unruh and Moomaw, 1998) that the existence of an endogenous 'self-regulatory market mechanism' for those natural resources that are traded in markets might prevent environmental degradation from continuing to grow with income has been suggested. Economic development may strengthen the market mechanism such that a developing economy may gradually shift from non-market to market energy resources that are less polluting (Kadekodi and Agarwal, 1999).

3.2.4.1. Role of price. The early stages of growth are often associated with heavy exploitation of natural resources due to relative importance of the agricultural sector. This tends to reduce the stock of natural capital over time. Efficiency in use of natural resources increases after a certain stage of development has been reached, as markets for environmental resources develop and prices begin to reflect the value of natural resources. The consequent increase in the price of natural resources reduces their exploitation at later stages of growth as well as environmental degradation associated with it. Moreover, higher prices of natural resources also contribute to accelerate the shift toward less resource-intensive technologies (Torras and Boyce, 1998). The rising oil price during the 1970s promoted shift to alternative sources of electricity power production (Unruh and Moomaw, 1998). Hence, not only induced policy interventions, but also market signals may explain the shape of EKC.

3.2.4.2. Role of economic agents. Among other things, the relationship between economic growth and environmental quality will be determined by the way economic agents (including citizens, businesses, policy makers, regulators, non-government organizations and other market participants) react to economic growth and its side effects. Market agents can also play an important role in creating pressures for environmental protection. For example, bankers may refuse to advance credit because of the environmental liabilities; consumers may avoid products known to be heavy polluters. Evidence suggests that capital markets also play an important role in encouraging cleaner products (Dasgupta et al., 2001a,b; Gupta and Goldar, 2003; Lanoie et al., 1998). Heavy emissions may also give signal to investors about firm's production techniques, which are inefficient (Lanoie and Laplante, 1994). The news related to environmental damage due to firm's production activities affect the stock prices (Hamilton, 1995; Dasgupta et al., 2001a) and subsequently such environmental news may help to reduce emissions (Konar and Cohen, 1997) as shareholders discourage it and also create pressure to adopt new technology. Shareholders of high-income countries drive heavy polluting firms to relocate to low-income countries (Levinson, 1996), and thus, investors also encourage clean production.

3.2.4.3. Transition to market economy. A country's transition from a centrally planned to a market-driven economy, or, in theory at least, transition from complete market failure to less market failure is consistent with an overall improvement in environmental quality. The environment in the transitional economies is cleaned up quickly because of rising energy prices and penalizing of energy-intensive activities (Nilsson, 1993; Vukina et al., 1999).

3.2.4.4. Information accessibility. Degree of competition in the market depends on the information about the product quality and production process. Given the stock nature of many pollution problems, emissions only partially account for the environmental impacts. Other than economic growth, several other variables like income distribution, education, information accessibility, etc., may also help to determine environmental quality (Bimonte, 2002). Social policy decision heavily depends on information accessibility corresponding to the position of economy as well as that of environmental quality. Thus, the information

[16] There has been intense pressure from environmentalists and policy makers to include environmental standards in trade agreements.

accessibility may play a vital role to curve down the pollution level through proper regulations.

3.2.5. Regulation

3.2.5.1. Formal regulation. Pollution grows unless environmental regulation is strengthened (Hettige et al., 2000a). With economic growth, economies advance with their social institutions that are essential to enforce environmental regulation (Dasgupta et al., 2001b). Developing countries are moving, now, from command-and-control policies to market-oriented forms of regulation (Dasgupta et al., 2002; Panayotou, 1999; Vukina et al., 1999). Information about polluters, damages, local environmental quality, abatement, etc., significantly improve the ability of regulators to enforce environmental standards. Market agents also reward clean firms and punish heavy polluters. Environmental regulatory institutions are either weak or absent in less developed countries. In this situation, pollution can be reduced if these poor countries focus on few sources, which are responsible for most of the pollution (Hettige et al., 1995). So, targeting regulatory monitoring and enforcement on those dominant sources can significantly reduce emissions.

3.2.5.2. Informal regulation. When formal regulation is weak or absent, societies often use other channels to induce pollution abatement by local factories through a process of 'informal regulation'. The resulting 'pollution equilibrium' reflects the relative bargaining power of the community and the plant (Pargal and Wheeler, 1996). For example, Agarwal et al. (1982) describe a situation where confronted by community complaints a paper mill in India installed pollution abatement equipment and also compensated residents for repairing the damage caused. Non-Governmental Organizations (NGOs) and social groups (including religious institutions, social organizations and politicians) may pursue informal regulation[17] (Dasgupta et al., 2002; Afsah et al., 1996). Evidences[18] from Asia and Latin America show that neighbouring communities can strongly influence factories' environmental performance. Actually, informal pressure has to be highly localized. A proactive vernacular media is one such localized informal regulation that can easily trigger formal regulations[19] that reduce emission level. So, the design of policy instruments for industrial pollution in the case of developing countries is very challenging[20] (Xu, 1999). Thus, in principle, the regulator has an array of physical, legal, monetary and other instruments such as property rights.

3.2.5.3. Property rights. Most of the resource base may be treated as a commons in primitive societies. With growing scarcity, times come when some aspects of the commons become defined as private property. Private property is the most incentive-enriched form: Individuals have greater incentive to manage, to conserve and to accumulate wealth that can be traded or passed to future generations. The economic progress is determined partly by the extent to which environmental assets are protected by private property rights[21] (Chichilinsky, 1994; Lopez, 1994). Countries with a high degree of private ownership and proper allocation of property rights have more efficient resource allocation, which help to increase income and decrease environmental problems (Cropper and Griffiths, 1994). A new approach to the EKC relationship is adopted to incorporate policy consideration (Panayotou, 1997). Policies related to secure property

[17] Two major formal channels of informal regulation are (i) reporting violations of standards to the regulatory agencies and (ii) putting pressure on regulators (through politicians and administrators) to tighten the monitoring and enforcement. These pressures vary from region to region, but the basic pattern remains the same everywhere. However, there also exist *informal* channels of informal regulation—like public disclosure, rating, etc., where use of market is made to punish polluters.

[18] See Afsah et al. (1996), Dasgupta et al. (2000), Hartman et al. (1995), Hettige et al. (1996, 2000a), Huq and Wheeler (1992), Pargal and Wheeler (1996) and World Bank (1999).

[19] In India, (High/Supreme) Courts direct the Government to implement law and regulations to control pollution or shut down dirty industries, or sometime, order to shift polluting industries to other places. For example, the Supreme Court has directed to West Bengal Government to shift tannery industries from Kolkata to Bantala within 2002.

[20] Informal regulations are not directly reflected in EKC generating data in low-income countries, but these are indirectly help to reduce pollution and thereby shape EKC through policy designs.

[21] Chichilinsky (1994) develops a model using environment as a factor of production with two regions: North and South. In this model, trade is harmful to South, and to the World as a whole, because too much environmental degradation occurs. His analysis is based on property rights.

rights under a rule of law and better enforcement, and effective environmental regulations can help flatten the EKC. Thus, the EKC may be a proxy for a property rights model that begins with a commons and ends with private property rights.

4. Theoretical analysis of EKC

The conceptual arguments make the EKC conceivable from a theoretical viewpoint. Recently, the EKC has been explained theoretically. Income growth is driven by accumulation of production factors (Lopez, 1994), which increases firms' demand for polluting inputs. At the same time, demand for environmental quality rises with income as the willingness to pay for a clean environment increases. A basic comparative static analysis of the costs and benefits associated with a better environmental quality provides an interesting conceptual insight as to how the EKC might emerge. The Environmental Kuznets Curve is derived from the interaction points of marginal cost (MC) and marginal benefit (MB) curves (Munasinghe, 1999). An EKC can be derived directly from the technological link between consumption of a desired good and abatement of its undesirable byproduct[22] (Andreoni and Levinson, 2001). It is also consistent with either Pareto efficient policy or a decentralized market economy. If pollution is not priced, firm will use it until its marginal product is zero, when pollution is considered as a factor of production, but not the stock of environmental capital. Extending this model, stock of environmental quality is included as a factor of production (Lopez, 1994), then the predictions of this model depend crucially on the existence of property rights. The EKC emerges from a dynamic process, as one part of capital goes for development of the environmental sectors. Total capital is divided into two parts—one is used in production process that creates pollution and damage the existing environment and the other is used to clean up environment or improve it (Dinda, 2002). The role of abatement expenditure is crucial to reduce the pollution in production side (Dessus and Bussolo, 1998; Jaeger, 1998; Selden and Song, 1994). But the abatement expenditure may not be a determining factor behind the EKC for long-lived pollutants like hazardous waste sites that are neither easily abated nor shifted elsewhere. A stylized theoretical model of the EKC based on perfect mobility of household and labour is developed, and a general equilibrium model that emphasizes spatial separation on the consumer side as the reason behind the EKC for hazardous waste sites[23] (Gawande et al., 2001). Under various conditions, the EKC relationship between pollution and income can be obtained theoretically (Beltratti, 1997; Bulte and van Soest, 2001; Dinda, 2002; John and Pecchenino,[24] 1994; Jones and Rodolfo, 1995; Kadekodi and Agarwal, 1999; Selden and Song, 1995; Stokey, 1998). It should be noted that the EKC relation may also take shape from the interaction between ecological and economic factors (Ezzati et al., 2001).

4.1. Empirical evidence for EKC

The empirical evidence for the existence of an EKC has been found in various studies. These studies share some common characteristics with respect to the data and methods employed. Most of the data used in these studies are cross-sectional panel data. The following reduced form model is used to test the various possible relationships between pollution level/environmental pressure and income:

$$y_{it} = \alpha_i + \beta_1 x_{it} + \beta_2 x_{it}^2 + \beta_3 x_{it}^3 + \beta_4 z_{it} + \varepsilon_{it} \quad (1)$$

where y is environmental indicators, x is income and z relates to other variables of influence on environmental degradation. Here, the subscript i is a country, t is time, α is constant, β_k is the coefficient of the k explanatory variables. Model (1) provides us to test several forms of environment–economic development/growth relationships:

(i) $\beta_1 = \beta_2 = \beta_3 = 0$. A flat pattern or no relationship between x and y.

[22] It is a simple and straightforward static model of the microfoundations of the pollution–income relationship.

[23] Gawande et al. (2001) first attempted to develop a consumption-based theory of the EKC.

[24] They have used overlapping generation growth model.

(ii) $\beta_1>0$ and $\beta_2=\beta_3=0$. A monotonic increasing relationship or a linear relationship between x and y.
(iii) $\beta_1<0$ and $\beta_2=\beta_3=0$. A monotonic decreasing relationship between x and y.
(iv) $\beta_1>0$, $\beta_2<0$ and $\beta_3=0$. An inverted-U-shaped relationship, i.e., EKC.
(v) $\beta_1<0$, $\beta_2>0$ and $\beta_3=0$. A U-shaped relationship.
(vi) $\beta_1>0$, $\beta_2<0$ and $\beta_3>0$. A cubic polynomial or N-shaped figure.
(vii) $\beta_1<0$, $\beta_2>0$ and $\beta_3<0$. Opposite to the N-shaped curve.

From these, we observe that the EKC is only one of the possible outcomes of model (1). From (iv), the TP of EKC is obtained at $x^* = -\frac{\beta_1}{2\beta_2}$.

A large number of econometric studies have used the model (1)[25] to test for the emergence of an EKC in a wide variety of income based environmental pressure/pollution levels.

4.2. Empirical findings

The empirical analyses are based on data for various sources. Most of the data used in empirical tests are drawn from cross-sections of countries, cross-sectional panel data and pooled data. Most of the studies have used water and air pollution data from GEMS, ORNL (CO_2), World Resources, UN Statistical Yearbook, compendium of the OECD, FAO Production Yearbook, WHO's Health database, IEA, EPA for US data, different sources for micro-data, etc. Economic data (GDP per capita, trade, etc.) are taken mostly from the Penn World Tables (Summers and Heston) or the World Bank. Using these data, several authors study the EKC hypothesis and their empirical evidences provide controversy about it. In the absence of a single environmental indicator, it is possible to distinguish three main categories that have been used in the literature: air quality, water quality and other environmental quality indicators.

4.2.1. Air quality indicators

The urban or/and local air quality indicators (SO_2: sulphur dioxide, SPM: suspended particulate matters, CO: carbon monoxide and NO_x: nitrous oxides, etc., directly affect human health) generally reveal the inverted-U relationship with income. Several studies[26] confirm this outcome. Generally, the literature does not find the evidence of EKC for air pollutants that have direct little impact on health. Both early and recent studies find that the global pollutants (such as carbon dioxide emissions) either monotonically increase or decrease as income grows.

4.2.2. Water quality indicators

For water quality indicators, empirical evidence of EKC is even more mixed. Three main categories of indicators are used as measures of water quality: (a) concentration of *pathogens* in water (fecal and total coliforms), (b) amount of *heavy metals* (lead, cadmium, mercury, arsenic and nickel) and *toxic chemicals* discharge in water by human activities and c) measure of deterioration of the water *oxygen regime* (dissolved oxygen, biological and chemical oxygen demand, i.e., BOD and COD). There is evidence of EKC for some indicators, but many studies reach conflicting results about the shape and peak of the curve (Beede and Wheeler, 1992; Hettige et al., 2000b). Several authors find evidence of N-shaped curve for some indicators (for example, fecal coliforms in river water, see Shafik, 1994).

4.2.3. Other environmental indicators

Some other environmental indicators (municipal solid wastes, urban sanitation, access to safe drinking water, energy use and traffic volumes, etc.) have been used to test the EKC hypothesis. Most of these indicators do not support EKC. All studies find that environmental problems having direct impact on human health (such as access to urban sanitation and clean water) tend to improve steadily with economic growth. On contrary, when environmental problems can be externalized (as in the case of municipal solid wastes) curve does not even fall at high-income levels. The empirical evidence of EKC is controversial in case of deforestation (Bhattarai and Hammig, 2001; Bulte and van Soest, 2001; Koop and Tole, 1999).

[25] Or the log value of the variables is used in Model (1).

[26] See Grossman and Krueger (1995), Selden and Song (1994), Stern and Common (2001), List and Gallet (1999), Shukla and Parikh (1992), Barbier (1997), Brandoford et al. (2000), Matyas et al. (1998), Jaeger et al. (1995), Ansuategi et al. (1998), Jha (1996), Horvath (1997) and Tucker (1995), Roca (2003).

4.2.4. Turning point

It is clear that the EKC-type relations exist for some environmental pressure factors and a transition is expected at a crucial point, i.e., turning point. The turning points of these inverted-U-shaped relationships vary for different pollutants or environmental indicators.[27] For most of the pollution indicators, the estimated turning point lies within the income range of US$3000–10,000 (at a constant price, 1985 US dollar). Moreover, there are also large variations across studies for same indicators. Economic growth may be associated with worsening environmental conditions in less developed or poor countries but air and water quality appears to be benefited from economic growth if the critical level of income has been reached. Several pollution indicators, such as SO_2, NO_x, CO, CO_2, SPM and air toxic emission matters; oxygen regime in river basins (BOD, COD), fecal contamination of river water, heavy metals in water (mercury, arsenic, cadmium, nickel, lead); hazardous[28] and municipal waste, deforestation (Bhattarai and Hammig, 2001; Koop and Tole, 1999), etc.; have been used to study the EKC relation. These studies assume that each country should follow EKC with same shape but level of the curve may vary across countries as per their economic position. The social and political factors are also crucial for shaping the EKC.

4.2.5. A meta-analysis

However, various EKC studies have employed different methods, evaluated several environmental indicators and used different data, resulting in a broad spectrum of findings and leading to sometimes conflicting interpretations. It is important to use meta-analysis to synthesize the EKC literatures. A meta-analysis is a statistical method of synthesizing results of similar empirical studies to determine whether credible conclusions about prior study results can be made. Methodological choices and pollutant types affect the estimated income turning point (Cavlovic et al., 2000).

4.3. Important lessons from the EKC studies

The EKC's paradoxical outcome inspired a large amount of research. A number of important lessons for the EKC debate are already emerging from the literature.

4.3.1. Local versus global pollution

The EKC relationships are more likely to hold for certain types of environmental damage, e.g., pollutants with more short-term and local impacts, rather than those with more global, indirect and long-term impacts (Arrow et al., 1995; Cole et al., 1997; John et al., 1995). The significant EKCs exist only for local air pollutants like SO_2, SPM, NO_x and CO (Cole et al., 1997), and urban air concentrations with a peak at lower income levels than total per capita emissions (Selden and Song, 1994). In contrast, the global environmental indicators (indirect impact) like CO_2, municipal waste, energy consumption (Horvath, 1997) and traffic volumes, either increase monotonically with income or have high turning points with large standard errors (Holtz-Eakin and Selden, 1995).

4.3.2. The role of national and local policy

Most of the EKC studies have concluded that income–environmental degradation relationship is likely to be affected significantly by national and local policies *ceteris paribus*. Several studies in this issue have attempted to estimate the influence of policy explicitly. The strong policies and institutions in the form of more secure property rights, better enforcement and effective environmental regulations can help to 'flatten' the EKC (Panayotou, 1997). In case of the Netherlands and West Germany, the impact of technological change in reducing SO_2 emissions is largely attributable to the installation of better *end-of-pipe* (EOP) abatement technology, which is in turn related to tougher environmental policy and regulation (de Bruyn, 1997). As income level rises, public spending on environmental research and development also increases. These R&D spending may not directly account for greater environmental improvement but also act as a catalyst for private spending on develop-

[27] For example, the TPs of different air pollutants occur at income of less than US$8000 per capita income (Grossman and Krueger, 1995), below US$10,000 (Selden and Song, 1994), lead emission at US$7000 (Hilton and Levinson, 1998) and hazardous waste at US$23,000 (Wang et al., 1998), hydrocarbon emission at US$35,000 per capita income (Kahn, 1998), etc.

[28] See Gawande et al. (2000, 2001), Bohara et al. (1999) and Berrens et al. (1997).

ment of cleaner technologies (Komen et al., 1997). The income of a country may be significant in determining the 'zeal and effectiveness' of its air pollution regulatory structure. Mainly because a richer state is likely to have more resources available to regulatory agencies, higher public preferences for improved air quality and a greater perceived danger from emission (Carson et al., 1997).

4.3.3. Country specific effects

A more fruitful approach to the analysis of the relationship between economic growth and environmental impact would be the examination of historical experience of individual countries, using econometric and also qualitative historical analysis (Stern et al., 1996). There is a large difference in state level per capita emissions due to the enforcement of federal pollution laws and possibly employment of outdated industrial technology in some states of the USA (Carson et al., 1997; List and Gallet, 1999; Selden et al., 1999). The increasing relationship between SPM and income in Malaysia may be due to the fact that low-income states are still sources of emissions because of land conversion through burning and replanting of tree crops, while high-income states are emitting increasing emissions because of industrial and municipal wastes (Vincent, 1997). Rapid urbanization and industrialization, which are correlated with rising income in Malaysia, are responsible for the increasing concentrations of ammoniac nitrogen and P^H in water, as expansion of municipal and industrial sewage treatment has lagged behind (Vincent, 1997).

The sources of EKC are summarized into two major groups: (a) structural change and (b) technological progress.

4.3.4. Structural change

Several authors have attempted to explore empirically which structural factors are responsible for EKC. The *scale* and the *composition* of economic activity, and *techniques* of production (Grossman and Krueger, 1991; Vukina et al., 1999; Xiaoli and Chatterjee, 1997), which may lend explanatory power to the observed relationships between income levels and measures of environmental impacts. Although structural change is a very intuitive notion, empirical evidence is found for the impact of difference in the structure of production on toxic manufacturing emissions (Lucas et al., 1992). Several authors have tried to explain the downward segment of EKC in different ways.

4.3.4.1. Production structure. Developed countries have fairly stable production structures, whereas rapidly industrializing and developing countries have unstable production structure and the effects of structural change on emissions may be less obvious. In comparison, structural change is less important than technological innovation, represented by the change in emission intensity across sectors, in explaining declining SO_2 emissions in the Netherlands and West Germany (de Bruyn, 1997). Structural changes have not been a dominant factor in reduction of SO_2 emissions in either country, at least during the 1980s. The changes in production structure in developed economics are not accompanied by equivalent changes in composition of production. The hypothesis of spatial displacement of environmental impacts and empirical evidences also reflect the composition of consumption instead of production. A change in the composition of consumption has resulted in a downward turn in pollutants (Rothman, 1998).

4.3.4.2. Migration. The solution of environmental problems associated with growth must mean more than *passing them off* to people in other time and places. It can be speculated that improvements in environmental quality may in reality be indicators of increased ability of consumers in wealthy nations to distance themselves from environmental degradation associated with their consumption. To extend this speculation, mechanisms for such distancing might include both moving polluting sources (viz., flow pollutants which is emphasized by Rothman, 1998) and selected households moving away from pollution concentration (viz., stock pollutant which is the study of Gawande et al., 2000). Considering general hypothesis of 'distancing' as a possible source of EKC results in which internal migration plays a central explanatory role for an observed EKC for hazardous waste sides (Gawande et al., 2000, 2001; Wang et al., 1998).[29] Different social groups are differentially able to migrate away

[29] Their results may inform the development of structural models (rather than reduced form model) relating economic growth and environmental quality.

from areas with critical build-ups of hazardous waste sites, then a migration mechanism is likely to be a source of increasing environmental inequality. Thus, migration is an important factor behind an EKC.

4.3.4.3. Share of GDP. A high share of manufacturing in total GDP is associated with higher levels of energy consumption. The importance of trade in combination with composition of economic activity is investigated in the decomposition of EKC for SO_2 concentrations across countries (Kaufmann et al., 1998). The effect of shifts in the sectoral structure of economy (Panayotou, 1997) can be represented by industry's share of GDP (Dinda et al., 2000; Friedl and Getzner, 2003). It should be noted that the manufacturing share in developed economies starts to decline rapidly after oil crisis.

4.3.4.4. External shock. The oil crisis in the 1970s affects individual country's production. There is a positive correlation between CO_2 emission and income for the pre- oil shock period (i.e., before 1973) and a negative correlation for the post oil shock crisis (Unruh and Moomaw, 1998). The EKC analyses is largely attributable to structural economic transition, and a significant *break* in the positive CO_2 emission–GDP correlation is found only in 16 OECD countries (Moomaw and Unruh, 1997). It is clear from the evidence that emission levels decline in every nation after the oil shock in the 1970s.

4.3.4.5. Corruption. The modified EKC analysis is also ready to allow for differences in EKCs between countries due (for instance) to inter-country variations in the presence of corruption. One of the determinants of environmental policy is the socio-political regime of a particular country. Corruption and rent-seeking behaviour can influence the relationship between income and environment (Lopez and Mitra, 2000). However, for any level of per capita income, the pollution levels corresponding to corrupt behaviour are always above the socially optimal level. So, the turning point of EKC takes place at income and pollution levels above those corresponding to the social optimum, which depends on the existing social institutions.

4.3.4.6. Institutional change. Along with economic development, societies advance with their social, legal and fiscal infrastructures that are essential to enforce environmental regulation[30] (Bhattarai and Hammig, 2001). Institutional changes triggered by citizens' demand for cleaner environments are more likely to occur in democratic countries. The influence of political and civil rights on these are better in more democratic countries (Shafik and Bandyopadhyay, 1992). However, opposite results can be found when the samples are divided into a subset of high- and low-income countries (Torras and Boyce, 1998). Most of the pollutants investigated in their study are substantially lower in more democratic low-income countries. Population density causes an increase in threatened species with the effect strongest in low-income countries. More species are threatened where freedom (political rights and civil liberties) is limited (McPherson and Nieswiadomy, 2001).[31]

4.3.5. Technological progress

Generally, technological progress leads to greater efficiency in the use of energy and materials. Thus, a given amount of goods can be produced with successively reduced burdens on natural resources and environment. One aspect of this progress may be better and more efficient reuse and recycling of materials, which (coupled with greater efficiency in use) can yield large resource savings.

4.3.5.1. R&D. As income grows, people can adopt better and efficient technology that provide cleaner environment. This preferential behaviour of people should be reflected through their income elasticity. The income elasticity of public research and development funding for environmental protection is positive (Komen et al., 1997). It is true for public expenditure on R&D for environmental protection in the case of 19 OECD countries over the period 1980–1994 (Magnani, 2000). This indicates the key role of such public investments for environmental improvements in reducing environmental degradation as income

[30] In case of weak regulators, different social groups and local communities pursue informal regulation and often use other channels to induce pollution reduction by local factories in a process of 'informal regulation' (Pargal and Wheeler, 1996; Dasgupta et al., 2002; Afsah et al., 1996).

[31] They analyze EKC issue using 1996 data on threatened bird and mammal species and per capita income levels for 15 countries.

levels rise and even decreasing relationships found for some pollution indicators in developed countries. The effect of economic growth on pollution/emissions differs substantially among high-income countries. Relative income[32] and political framework in which policy decisions are taken determine the emergence of downward sloping segment of EKC. This also depends on the adoption of new technology.

4.3.5.2. Innovation and adoption. New technologies, unambiguously, improve productivity but create potential dangers to the society such as new hazardous wastes, risk and other human problems. These externalities are unknown in the early phase of diffusion of technology, in later stages regulation becomes warranted to address it. Once the technology is regulated, this may stimulate the gradual phase out of existing technology. So, a cyclical pattern arises in technologies, which first diffuse, then become regulated and finally are phased out by next generation of technologies (Smulder and Bretschger, 2000). Thus, an inverted-U shape can be observed with reference to each technology. Since the pattern of innovation, income growth and pollution over cycles, a sequence of Environmental Kuznets Curves emerge related to each technology. This may produce an envelope of EKCs, which may be again an inverted-U- or N-shaped or inverted-L curve (Dinda, 2003b). The Environmental Kuznets Curve hypothesis is confirmed with empirical evidence for several pollutants. Earlier EKCs studies provide that some pollutants follow N-shaped relationship with income, and pollutants have different turning points. This implies that over a certain period during which income grows, one pollutant may decline but another may rise due to adoption of new technology.[33]

4.3.5.3. Technological and organizational change. Improved technology not only significantly increases productivity in the manufacture of old products but also the development of new products. There is a growing trend among industries to reconsider their production processes and thereby take environmental consequences of production into account. This concerns not only traditional technological aspects but also the organization of production as well as the design of products. Technological changes associated with the production process that may also result in changes in the input mix of materials and fuels (Lindmark, 2002). Material substitution may be an important element of advance economics (Labys and Wadell, 1989) that may result in lower environmental impacts. The economy-wide reforms often contribute simultaneously to the economic, social and environmental gains (Anderson and Cavandish, 2001; Pasche, 2002). The EKC approach seeks to relate the stages of economic development of a country to that of environmental degradation. Developing countries could learn from the experiences of industrialized nations, and restructure growth and development to *tunnel* through (Munasinghe, 1999) any potential EKC—thereby avoiding going through the same stages of growth that involve relatively high (and even irreversible) levels of environmental harm.

However, it is not clear which effective environmental policies should encompass to reduce pollution. Yet, virtually all of the studies that investigated EKCs have hinted at the important policy implications of their work.

5. Policy implication for EKC

Now EKC has become standard fare in technical conversations about environmental policy. Understanding the impact of economic growth on environmental quality is becoming increasing important as environmental concerns are making their way into main public policy agenda (Anderson and Cavandish, 2001). The policy implication of EKCs is that promoting economic growth are sufficient criteria to safeguard the environment. In the long run, the surest way to improve the environment is to become rich[34] (Beckerman, 1992). But environmental policies may or may not be implemented when economy develops (Shafik and Bandyopadhyay, 1992). There are several

[32] A gap between country's ability to pay (ATP) for environmental protection and a country's willingness to pay (WTP) provide the existing income inequality (Heerink et al., 2001).

[33] Some pollutants are phased out completely in developed economies (CFC), while other pollutants are rising (CO_2). There is no evidence, therefore, that a relevant composite index of pollution declines with income.

[34] Various authors have criticized these conclusions, most significantly in an article by Arrow et al. (1995).

points that impede a clear policy conclusion derived from the EKCs: Few questions are raised regarding EKC related policy, such as: (i) Is EKC valid for all types of environmental pressure? (ii) Is EKC permanent? (iii) Is EKC valid both for individual countries and the World? and, lastly, (iv) Does EKC follow a sustainable development path? Positive answers to these questions would grant the EKC policy relevance. Negative answers would indicate that the validity and policy relevance of EKCs is partial—partial with respect to countries, indicators, time and cost-effectiveness.

5.1. Is EKC valid for all types of environmental pressure?

Empirical evidences suggest that environmental problems may be solved at higher levels of income only for some environmental quality indicators. This is true when there is a direct link between environmental quality and human health impacts (Gangadharan and Valenzuela, 2001). The EKC applies only to environmental problems that are easy to solve and which are well documented and well known. Most of the air pollutants (that have been investigated) are energy related, such as SO_2, NO_x, SPM, CO and CO_2. EKC is valid for SO_2, CO emissions and particulate matters, etc., other pollutants follow either monotonicity or N-shaped.

5.2. Is EKC permanent?

The EKC hypothesis assumes that the initial increases in environmental pressure are temporary, but that the subsequent decreases in environmental pressure are permanent. Only a few authors have questioned whether these observed decreases could also be a temporary phenomenon due to technological limitation (Dinda et al., 2000). The result would be an 'N'-shaped curve.[35] An upswing of EKC can be explained by the difficulty of keeping up efficiency improvements (innovation) with continuing growth of production. On an aggregated indicator of material and energy throughput suggest that the second half of the 1980s most developed economies have gone through a phase of *re-linking* their throughput with economic growth (de Bruyn and Opschoor, 1997). The fact that re-linking cannot be found for pollutants such as SO_2, particulate matter and CO_2 may reflect the continuing importance of end-of-pipe solutions over more fundamental changes in the economy, such as reducing throughput. Pollutants for which the end-of-pipe solution is costly may follow a similar N-shaped pattern.

5.3. Is EKC valid both for individual countries and the world?

Generally, the EKC is estimated in a cross-section panel of countries. Such estimates do not guarantee that over time individual countries will move along the estimated relationship (de Bruyn et al., 1998). The results of panel countries and that of individual or sub-sample countries vary widely (Dijkgraaf and Vollebergh, 1998; Stern and Common, 2001). Developed countries are often associated with lower emission reductions but in developing countries, the environmental pressure increases over time. Developing countries have not yet reached income levels high enough to be able to derive their turning points. The worldwide emission prospects are not optimistic as it might be expected on the basis of EKC results. According to EKC hypothesis, the improvements in environmental quality are not attainable for the majority of the world population that has the standards of living substantially below the estimated turning points (Stern et al., 1996). Therefore, worldwide emissions are expected to continue to increase due to economic growth (Selden and Song, 1994).

5.4. Does EKC follow a sustainable development path?

EKCs represent the patterns of flows of pollutants, whereas environmental impacts are often characterized as a stock problem (Arrow et al., 1995). The EKC, therefore, does not necessarily reflect a sustainable time path of pollution (Dinda, 2003a; Ekins, 1998; Gruver, 1976; Zang, 1998). Maximum level of pollution depends on costs and benefits of pollution abatement, which differ among countries. Differences in absorptive capacities, social preferences and discount rates give rise to different costs–benefits struc-

[35] De Bruyn and Opschoor (1997) and Sengupta (1997) found N-shaped curve. Grossman and Krueger (1995) also found it for SO_2.

tures, which implies different optimal levels of pollution among countries. This limits the policy relevance of an estimated collective turning point for a whole sample of countries. There is no guarantee that the rising part and top of EKC bypass ecological thresholds and sustainability constraints beyond which environmental deterioration is irreversible (Arrow et al., 1995; Panayotou, 1993).

5.5. Socio-political regime

Restructuring the environment may become unnecessarily expensive, and it may be less costly to prevent or abort today than in future. Most of authors agree that environmental policies are key determinants of the future path of income–environment relationship. Actually, public preferences are reflected through environmental quality related public policy that influence the relationship between income and pollution. In other words, researchers have identified some demand-side characteristics that influence the state's environmental policy regime, and they also explained the mechanism through which these preferences are manifested.

Provision of public good, especially with regard to air and water quality, comes from state because individuals of the society are unable to purchase abatement technology directly. So, the environmental policy is a function of the preferences of society. Actual levels of environmental quality depend on weights placed on various heterogeneous societal preferences by policy makers, which can be generally characterized as the policy regime. One major determinant of environmental policy is the socio-political regime of a particular country. Corruption and rent seeking behaviour may influence the income–environment relationship (Lopez and Mitra, 2000). A well-defined property rights, democratic voting systems and respect of human rights can create synergies, which lead to increased levels and efficacy of environmental policy[36] (Magnani, 2000).

Policies are generally formulated at national level and it is implemented at local levels. These command-and-control policies are inefficient and ineffective because policy makers suffer from lack of proper information about local environmental damage. Local communities should properly protect their environment. The demand for environmental protection therefore comes from local levels to national levels, which thereby leads to global level. It is demand led policies that are emerging which will actually rule the Future World.

6. A critique

The Environmental Kuznets Curve model has elicited conflicting reactions from researchers and policymakers. The stakes in the EKC debate are high for both developing and developed countries. It is clear that EKC can take shape from a multiplicity of possible outcomes of economic development. So, proper attention is required for multiple factors that form the economic–environmental system, rather than a single dominant one (Ezzati et al., 2001). Since these factors are interdependent, it is difficult to determine the factors that may dominate and govern the shape of EKC. The uses of reduced form models,[37] as explained above, deny any insight into the underlying causes of EKCs. The lack of insight into the process that causes pollution to curve downwards beyond a particular income level makes designing of specific policy implications from an EKC difficult. The EKC analysis thus has significant deficiencies. There are increasing grounds to be cautious about EKC hypothesis.

6.1. A conceptual critique

As already mentioned, the inverted-U relation or EKC cannot be generalized for all types of pollutants. There is little empirical support for an inverted-U-shaped relationship between income and several important air pollutants (Harbaugh et al., 2002). Environmental indicators, for which the EKC hypothesis is most plausible, are various indicators of air pollutants

[36] The EKC is observed for some pollutants underlying the process of growth and structural change, and demand shifts are also slow and gradual. It takes several decades to improve environmental quality unless active environmental policy intervenes. The possible insight is the advance of a country along its EKC may not only relate to its own level of economic development and environmental policies, but also to its competitive position relative to other countries (Panayotou, 1999).

[37] Since both income and environmental quality are endogenous variables, i.e., the impact each other, therefore, the estimation of single equation relationships where simultaneity exists will produce biased and inconsistent estimates (Hung and Shaw, 2002).

such as SO_2 and SPM. However, this EKC relation is only confirmed for pollutants involving local short-term cost (for example, SPM, SO_2, CO, etc.), not for the accumulated stocks of waste or for pollutants involving long-term and more dispersed costs (such as CO_2), which are often increasing functions of income. For example, for some pollutants, notably CO_2 emission, the EKC relationship does not hold in any meaningful way (Holtz-Eakin and Selden, 1995; Dinda, 2001; Robers and Grimes, 1997).

The EKC may not hold even in the long run (de Bruyn et al., 1998; Dinda et al., 2000). Economy can foresee a so-called N-shaped curve, which exhibits the inverted-U curve initially, but beyond a certain income level, the relationship between environmental pressure and income turns positive[38] again. This suggests that the *re-linking hypothesis* may be plausible (de Bruyn and Opschoor, 1997; Sengupta, 1997). For example, the levels of aggregate materials consumption over time may show an N shape rather than an inverted-U shape.

Environmental quality also degrades due to water pollution. The relationship between industrial share of national output and industrial water pollution follows a Kuznets-type trajectory. However, other two determinants (share of polluting sectors in industrial output and end-of-pipe pollution intensities in polluting sectors) do not (Hettige et al., 2000b). Moreover, the EKC relation does not hold even for total industrial water pollution and toxic pollution (Lucas et al., 1992; Hettige et al., 2000b).

Environmental quality may also deteriorate as population pressure increases more and more. It is clear from the existing literature that most of the world's population lies on the upward sloping portion of EKCs. This implies that, even if the EKC exists, income growth across the global population will increase environmental damage (Ekins, 1997). Such damage is considered to be the main obstacle or hindrance to attaining sustainable development (O'Neill et al., 1996). Thus, economic growth may not automatically lead to a higher environmental quality and only strong pressure for environmental policy[39] may help in this regard (Grossman and Krueger, 1995).

Environmental policy is designed on the basis of empirical findings, which actually depends on the choice of appropriate variables (measured in terms of relative or absolute level). Empirical studies have mostly used absolute measure of pollution like amount of emission or pollution rather than a relative measure (like pollution or emission per unit of output or per square kilometer, etc.). Use of a relative measure of pollution or emission, i.e., pollution intensity, may reveal a U shape or a monotonic relation with income rather than an inverted-U shape[40] (which may be true for absolute level). It should be noted in this context that the effect of income on pollution intensity tends to be negative in open economies, but positive in closed economies.

The objective of empirical study is not only to find the existing relationship but also to help predict the future. Forecasting (or predictions) of environmental quality actually depends on the estimated income–environment relationship (which is based on observed data). Prediction will be meaningful and correct if the existing relations hold in future. Predictive success is really a very limited conception over a longer period of time. For example, the immediate past has allowed much growth and technological progress that does not mean the same holds for an indefinite period of time into the future. The existence of EKC does not ensure to exist in future because of pressures of global competitions[41] for environmental standards and regulations. The EKC analysis does not yet establish the

[38] This is a secondary turning point (between income levels of US$10,000 and US$16,000; for instance, see Sengupta, 1997 and Dinda et al., 2000 and the footnotes in Grossman and Krueger, 1995) at which the levels of ambient air pollution tends to increase. This N-shaped relationship may be justified as an efficient technology improves the resource uses that have been exhausted, at the same time abatement opportunities become too expensive. In this situation, further income growth will result in net environmental degradations (De Bruyn et al., 1998).

[39] Better policies and institutional setup can help to flatten the EKC (Panayotou, 1997).

[40] Incorporating spatial intensity of economic activity may turn the relationship between per capita income and atmospheric concentration of SO_2 upside down (Kaufmann et al., 1998).

[41] The different pressure groups should be created for betterment of environment or to protect it. These pressure groups set up mainly on the regional basis like European Community (EC), North American Free Trade Agreement (NAFTA), SAARC Preferential Trading Agreement (SAPTA), etc. These pressure groups set up their own environmental standards and force to internationalize their standards. The top pressure group is the USA and European Union, who are so eager to adopt their environmental norms in the international level through World Trade Organization (see the results of recent WTO meetings in Seattle, 1999, Doha, 2001, and Cancun, 2003).

channels through which economic globalization affects the pollution levels or existing environmental quality (Tisdell, 2001).

Finally, the concept of EKC cannot be applied to all the environmental factors. For example, land-use change and/or bio-diversity loss, which are irreversible, are conceptually different from air or water pollution.

6.2. A methodological critique

As mentioned above, several authors have applied various methodologies in their empirical studies. Most of the studies have used cross-section data to examine the EKC hypothesis for group of countries and enough attention has not been given to country-specific EKC. The basic assumption behind pooling[42] the data of different countries in one panel is that economic development trajectory would be the same for all. This assumption should be criticized because wide cross-country variations are observed in social, economical, political and biophysical factors that may affect environmental quality. (For example, the percentage of forest covered area in total area varies from country to country.) Under such heterogeneity of conditions, the use of random effect model may be appropriate for examining shape of economic growth–environment relationship based on cross-country, cross-sectional data[43] (Koop and Tole, 1999).

It should be noted that the global environmental degradation (GED) level instead of country's pollution or emission levels due to economic development might be an important factor (for global EKC), which has been ignored in the existing EKC literature. Using environmental degradation index (EDI) and an appropriate measure of economic development (i.e., Human Development Index [HDI]), one can develop a global EKC model (Jha and Bhanu Murth, 2003). It should be noted that empirical support for the existence of a global EKC for CO_2 emissions[44] has not been found, although some meaningful relationships between income and CO_2 emissions in individual countries have been observed (Dijkgraaf and Vollebergh, 1998). The coefficient estimates for carbon emissions[45] for a panel of OECD countries differ from those obtained for individual country-specific time series that constitute the panel. Little attention has been paid to time series properties of the data, whether variables used in EKC are stationary or/and integrated (Perman and Stern, 1999; Coondoo and Dinda, 2002).

A number of relevant factors have so far been omitted in the EKC studies, such as transboundary and intergenerational externalities (Ansuategi et al., 1998; Copeland, 1996). Trade is supposed to be an important explanatory factor for EKC relationship. As argued above, high-income countries have greater emission reduction possibilities because they may shift polluting industries to other countries through trade. The export and import of manufactured goods are likely to be much stronger determinants of the level of energy consumption than income (Suri and Chapman, 1998). The amount of energy consumption depends on its prices. Thus, the energy price may be a relevant variable for explaining EKC (Agras and Chapman, 1999).

The non-availability of actual data on environmental quality is the major limitation of all EKC studies. Truly speaking, environmental quality is something that is not easy to be measured accurately. Therefore, an index of environmental quality, which could be better measurement, should be developed and used to examine the EKC hypothesis (Fare et al., 2001).

The empirical robustness of EKC relation still remains an open issue (Grossman and Krueger, 1996). The reduced form rather than structural form equations have been used in most of the EKC studies. Actually, environmental outcomes are related to endowments of individual countries but (economic measures in) reduced forms are silent about causal mechanisms.[46] More structural forms may warrant exploration, for some interdependence in our environmental indicators is probable (Dinda and Coondoo,

[42] A critique raises about assumptions underlying pooling of observations relating to different countries in one panel.

[43] With regards to the data, Stern et al. (1996) has criticized the deforestation data, which informed the analysis of Panayotou (1993) and Cropper and Griffiths (1994).

[44] The EKC may be a problematic concept, as simple global EKC models are mis-specified (Perman and Stern, 1999; Dinda, 2001).

[45] In this situation, non-parametric, Bayesian or/and agent-based approach can fit the data better than regression models (Taskin and Zaim, 2000; Halkos and Tsionas, 2001; Bartoszezuk et al., 2001).

[46] Causal mechanism is discussed in details in Coondoo and Dinda (2002).

2001). For example, use of pesticide may destroy useful insects or micro-organisms (and thus hamper soil fertility) or threaten bird species, but this kind of interdependence remains yet to be explored.

7. Conclusion

This paper reviews a number of studies on the Environmental Kuznets Curve hypothesis. The EKC hypothesis postulates an inverted-U-shaped relationship between different pollution indicators and income, that is, environmental pressure increases up to a certain level as income goes up, after that it decreases. An EKC actually reveals how a technically specified measurement of environmental quality may change as the fortunes of a country change. Evidence of the existence of the EKC has been questioned from several corners. Only some air quality indicators, especially local pollutants, show the evidence of an EKC. Moreover, there is no agreement in the literature about the income level (turning point) at which environmental degradation starts to improve. This paper discusses about the results, methods, explanations and policy implications of the studies that have found empirical evidence for the EKC hypothesis. A critical evaluation follows these discussions. There are increasing grounds to be cautious about EKC hypothesis and related policies. Environmental degradation, actually, is a multifaceted problem and different stages of environmental damage have some definite relations with economic growth. Since one such relation is EKC, which can be explained in multidimensional ways or in terms of multidimensional issues. From the EKC literature, it is clear that there is no single policy, which can reduce pollution levels with rising economic growth. However, the subject is open-ended and EKC analysis continues to be widely used. Evidence for the existence of EKC is inconclusive.

From this mixed evidence about the relationship of economic growth and environmental quality, we can draw some conclusions and some points require elaboration for future research. Firstly, we need economic models, which properly reflect the physical and ecological basis of economic activity, and important feedback between the economy and the environment. Secondly, identification of the dominant factors that explain the EKC should have a high priority in research. One can design a policy that affects the course of the EKC only when the factors behind EKC have been properly identified. Thirdly, estimation of structural models, instead of reduced-form models, may be needed to identify the actual mechanism for this purpose. Fourthly, decomposition analysis can provide more insight into which combination of explanations is dominant, such as technological progress and structural changes. Fifthly, in addition to panel data analysis, efforts should be devoted to time-series analysis that may provide a better picture of the development of pollution associated with specific phases of development in individual countries. Sixthly, on a political level (there is no automatic process) courageous policy measures are necessary to allow for economic sustainability. Lastly, in case of adoption of new technology, society should be cautious about the possible unknown pollutants and waste hazards.

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