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Economic Growth, Financial Development and CO_2 Emission: PSTR Approach

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Abstract
The aim of this paper is to assess the sign and magnitude of the nonlinear effects of main socio-economic variables as well as the financial development index (measured by private credit to GDP ratio) on environmental pollution. Specifically, the interaction of the socio-economic variables with financial development as a threshold variable in affecting CO2 emission is studied. In this respect the Panel Smooth Transition Regression (PSTR) technique is applied to a panel-data set for 16 middle income countries (including some countries of BRIC and Iran) during the period 1970-2013.It is found that the output level and energy use have a positive significant effect on CO2 emission although their effects at higher levels of financial development decrease and increase respectively i.e. financial development provides motivations for shifting to eco-friendly technologies but not being effective for applying fuel efficient technologies in energy consumption. Moreover, it is shown that as the economies reach higher levels of financial development, the effect of population on CO2 emission intensifies. As to the effect of financial development, it has a positive significant effect on pollution with a threshold level of 34 % for financial development index, i.e. up to this point, the effect of financial development on the pollution, rises at an increasing rate.

1. Introduction

Sustainability of a society has various aspects. One important aspect in this respect is the environmental sustainability. A significant element of sustainability is the healthy living standards which one of its determinants is the sound environment and ecosystem. There is no doubt that pollutants, and particularly, the CO2 emissions have profound effects on the environment which can be a threat to sustainability and therefore socio-economic resiliency of a country. In recent years' pollutants have had ever-increasing trends of emission in most countries especially those with middle levels of income. The following graphs show CO2 emissions per capita for two typical countries having middle level of income, i.e. India and Iran for the period 1960-2013 which can be

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considered as the representatives of the countries being in the lower and upper middle income group countries of the world.

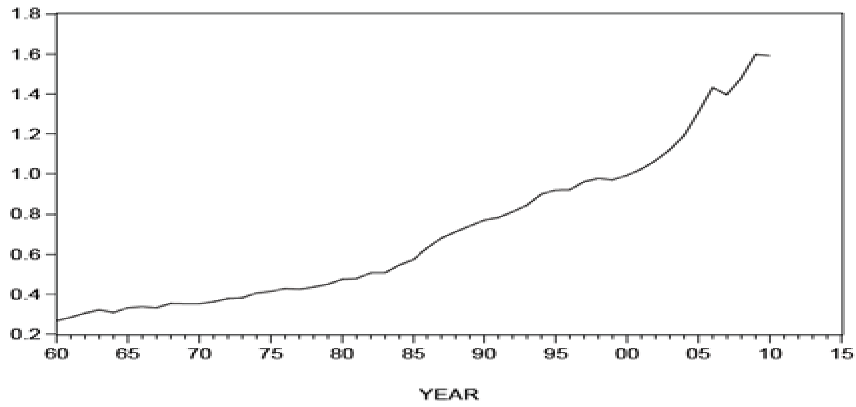

Figure 1: INDIA CO2 Emissions (metric tons per capia)

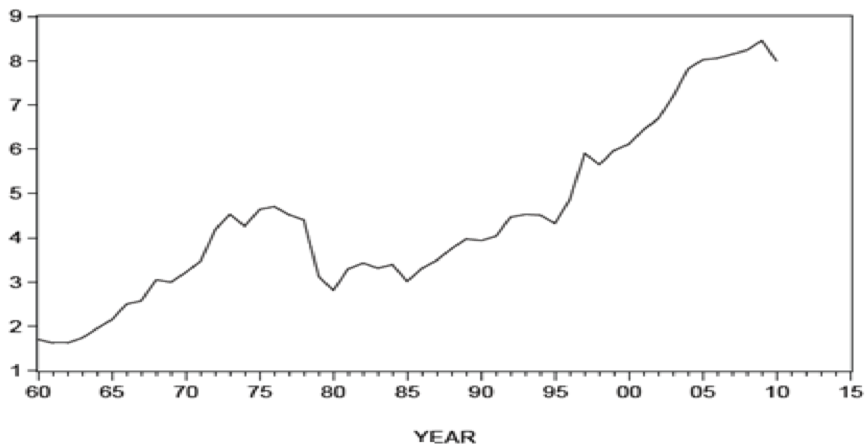

Figure 2: IRAN CO2 Emissions (metric tons per capia)

Source: The World Bank (data.worldbank.org/indicator)

These trends for pollutants which impose huge human and nonhuman costs on countries are alarming. This increasing trend of pollution is evident for all countries of middle income group. For example, CO_2 emissions for a sample of 16 countries in this group, i.e. Algeria, Argentina, Brazil, China, Colombia, Costa Rica, Ecuador, India, Iran, Mexico, Paraguay, South Africa, Thailand, Tunisia, Turkey, Venezuela is shown in Fig. 5.

The increasing levels of pollutant emissions are the result of high energy consumption. The Graphs 3, 4 depict energy use in India and Iran for the same time period.

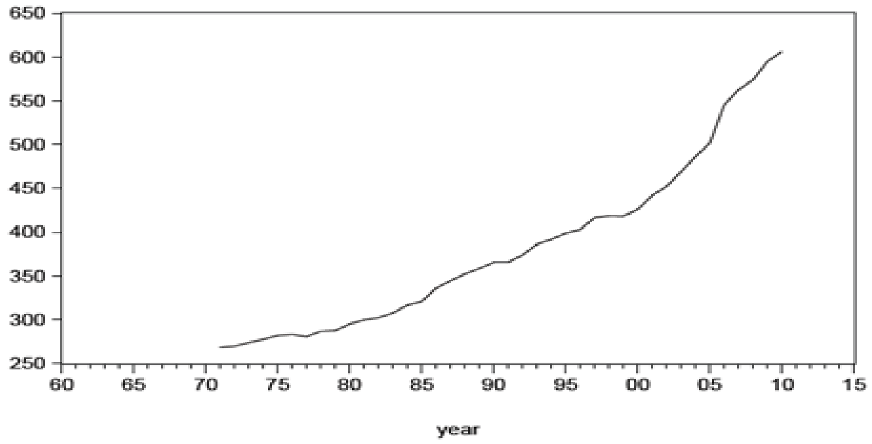

Figure 3: INDIA Energy use (kg of oil equivalent per capita)

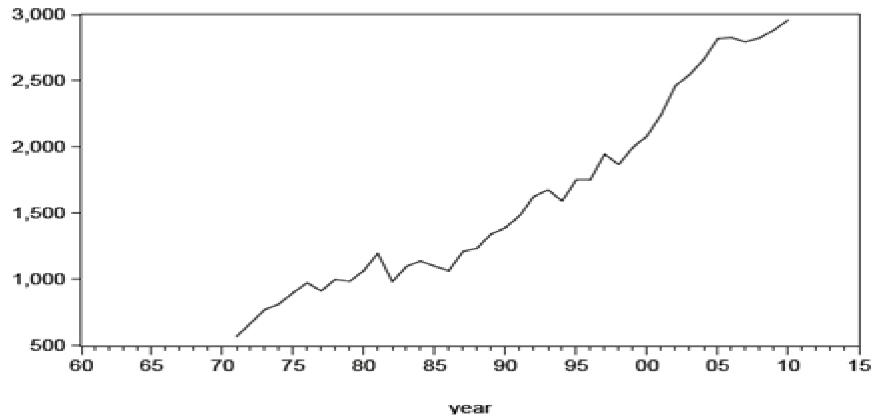

Figure 4: IRAN Energy use (kg of oil equivalent per capita)

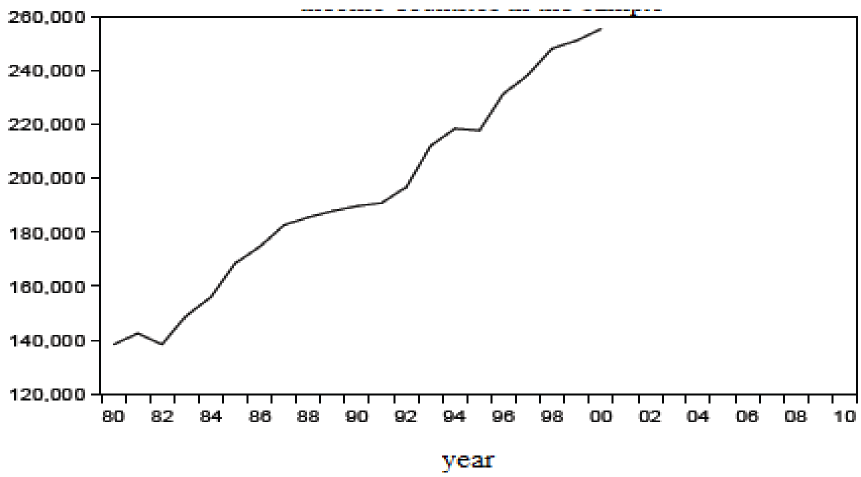

Figure 5: Averge CO2 emission for middle income countries in the sample
Source: The World Bank (data.worldbank.org/indicator)

As to variables affecting these pollutant emissions which are noteworthy to consider, it is evident that pollutants and their emissions are affected by many socio-economic, technological and perhaps financial variables. Some of these variables can be easily identified; energy use is one of these variables. It has, ceteris paribus a positive and direct effect on pollutants. As another variable, population can have adverse effects on environment, however its quality and age structure, its concentration in urban or rural area and the related elements of human capital should be carefully considered. For some variables, the type of relation is more complicated; the structure of energy systems and the energy mix is an example. Yet another set of variables seem to have mixed effects since their impact are dynamically different (their short and long run effects are not the same).

The functional forms by which they affect pollutants differ, that is the rate at which they affect pollutants is not constant and thus these forms are not necessarily linear. The level of economic activity and output, measured by GDP or its rate of change, i.e. economic growth is one such variable. Depending on the channels through which it acts (outlined in the review of the literature), it may have positive as well as negative net effects at the same time, different short and long run effects and different impact factor at various levels of the variable which indicate different functional forms. Therefore, various attempts have been made to capture the diversity of effects. On the one hand, for incorporating the possibility of dynamic effects in various time horizons (i.e. short and long run) time series techniques such as ARDL, VAR, cointegration and VECM analysis have been used. For considering dynamic mechanism of the relations, see Kolstadand and Krautkraemer (1993). On the other hand, for capturing the possibility of nonlinearities, different functional forms have been tried, of which, Environmental Kuznets Curve (EKC) type models are well-known. We may refer to the following studies which test EKC model: Coondoo and Dinda (2008), Managi and Jena (2008), Shahbaz et al. (2013a, b) and Tiwari et al. (2013). Another complicated variable of concern, which is expected to have effects on pollutants, is financial development. There are many channels through which financial development may affect pollution (see section 2). Again there are different counteracting short and long run nonlinear effects which depend on the level of financial development. Various studies on the subject try to capture these complications.

As a matter of fact, the relation between pollutants and related variables in reality cannot be linear. As mentioned above, the well-known forms of nonlinearity used in the literature are EKC-type models for either economic growth (or GDP) and financial development which without any other reservation for change of coefficients for variables have the following shortcomings:

i - Pure EKC models impose major restrictions on the relationship. Kuznets inverted-U curve assumes that up to a point for the independent variable (economic growth, GDP or financial development), environmental quality decreases and thereafter increases. In terms of a measure of environmental quality such as CO2 emission this implies an inverted-U shape relation. However, beyond the maximum point for the pollutant, the rate of decline will be increasing.

ii - The functional form used in pure EKC models assumes that by sufficiently increasing the independent variable (economic growth, GDP or financial development), we can arbitrarily reduce the pollutants even to a zero level. Obviously this is a major limitation for the research, because technological constraints prevent us to reduce pollutants to zero.

iii - Although the main independent variable enters nonlinearly in the relation, other variables have linear form.

Other nonlinear forms, in addition to a pure EKC structure, include sigmoid functional forms implied by logistic specification, which for the panel data set; it is referred by the term PSTR. PSTR model tries to handle the aforementioned shortcomings of EKC models as follows:

i- Upon reaching the local extremum of the variable for which we are estimating the threshold, there is no increasing rate of change in the dependent variable as indicated by a pure EKC form.

ii - The nonlinear relation does not imply that we can reach zero level of pollutants by arbitrarily increasing the independent variable.

iii - By multiplying the logistic term, other variables in the relation enter nonlinearly in the model.

iv - By incorporating different number of location, threshold parameters and regimes we may design highly flexible models.

In this paper, our aim is to determine factors affecting pollutions in a sample of middle income countries. The motivation for the present study is that the results of the studies covering wide range of countries based on the usual linear models (linear in parameters ;including EKC-type models) are mixed:

Some reach to a significant positive and some to a significant negative effect of economic and financial development on pollutants .Yet another group of studies discover no significant relationship, which may be due to heterogeneity of countries and/or the nonlinearity nature of the relations (see the review of literature).This study, by taking a nonlinear functional form to a more restricted set of middle income countries based on a more comprehensive model tries to reach more precise results for more specific homogeneous countries. To this aim, given the advantages outlined above on the combined PSTR functional form and EKC, a nonlinear regression model is applied to a set of panel-data for 16 countries (including Iran) during the period 1970-2013.

The organization of the paper is as follows: in the section 2, a review of the literature is presented. In this section, channels by which financial development can affect CO_2 emission are introduced. Empirical studies regarding the relationships are also presented. Section 3 deals with the estimation technique, data and variables. Section 4 is devoted to estimation results and relevant tests. Finally, discussion around the results is the subject matter of section 5.

2. Literature Review

2.1 Theoretical Foundations

2.1.1 Why Does Financial Development Affect Pollution?

There is a vast literature on the factors affecting environmental quality. One the one hand variables of economic performance such as GDP or economic growth have direct and indirect effects on pollutants. Population and energy use have also effects on pollutants. The dynamics of the effects differs in the short and long run. Moreover, the effects are nonlinear and depend on the level at which they are. Yet another affecting variable is the level of financial development. Since our focus is on this variable we may take a closer look at it. In the literature, financial development can have positive and negative sign in affecting CO_2 emission.

On the side of positive effects of financial development on CO_2 emission, we can refer to the following arguments:

Some researches emphasize on the role of financial development in removing credit and liquidity constraints. Some of these studies indicate that financial development reduces credit constraints for consumers, which enable them to purchase commodities that result in higher levels of CO_2 emissions. Automobiles, more transportation services demands, expansion of tourism, buying more energy using appliances and energy intensive goods are examples (Sadorsky, 2010). Other studies point out that financial development, reduce liquidity and credit constraints for large and small firms especially in manufacturing industries, which help them to expand output and economic activity that cause economy-wide CO_2 emissions (Dasgupta et al., 2001).

Another line of reasoning, which argues why financial development can positively affect the level of pollution emphasizes on the effects which are implemented through innovations. On the one hand, financial development can help financing technological innovations, which by introducing new commodities , combinations, firms and industries motivate higher levels of output and pollutants (Jensen, 1996).On the other hand, financial development, in association with financial innovations in an asymmetric information setting by reducing frauds through recognizing good entrepreneurs from bad ones, gives higher levels of economic growth and economic activity, which can increase pollutants.

Financial development facilitates investments in physical capital which can take different forms from both internal and external point of views. An important portion of these investments are in energy and especially in oil and gas industries. Capital formation in these industries will be easier if instruments provided by financial development are available (Kumbaroglu et al., 2008). Financial development can attract FDI which by producing energy consuming commodities causes more CO_2 and other pollutants (Halicioglu, 2009).

Extensive imports of energy consuming and energy intensive (especially if badly regulated) intermediate, capital and consumption goods are motivated by the finance provided and expanded by financial development (particularly if having low environmental standards), which produce more pollutants (Halicioglu, 2009).

Financial development promotes economic activities, which directly and indirectly result in more energy consumption that can increase pollutants. Some activities directly increase with financial development such as transportation and tourism and some activities are being indirectly influenced (Jalil and Feridun, 2010).

On the side of negative sign for the effects of financial development on CO_2 emission, we can refer to the following arguments:

Financial development helps financing more energy efficient projects in firms all over the economy, which contributes to reduction in pollutants (Tamazian et al., 2009). Specifically, one of the industries which are affected directly is transportation. In this regard big rural and urban public transportation projects, which help to improve environment and reduce pollutants, require huge funds and financings that can be provided by financial intermediaries. Financial development provides better settings for the activity of such institutions (Khan and Baig, 2009).

One channel through which financial development affects pollution is research and development (R&D). Financial development helps R&D programs which have positive dynamic effects on environment and reduce CO_2 emissions especially in the long run. This efficiency effect as different from scale effect is emphasized by some authors (Zhang,2011).Financial development can attract more FDI, which in turn brings about higher levels of R&D that leads to less pollutants (Frankel and Romer, 1999).This can be done by developing new more efficient technologies, which reduce the emissions (Talukdar and Meisner ,2001; Meilnik and Goldemberg ,2002; Wang and Jin, 2007; and Bello and Abimbola, 2010).

Environment and finance have mutual interactions. Eco-friendly arrangements (NGOs and other national and international organizations) have introduced eco- friendly firms and industries to the public for which providing funds and financings will be easier especially if the economy is financially developed (Lanoie et al., 1998). Moreover, investment in renewable energies, which are generally eco-friendly, requires huge amounts of funds which the development in financial sector can provide those (Tamazian et al., 2009). Joint projects implemented by environmental regulators and capital markets, result in reports on environmentally successful firms, which motivate eco- friendly measures. Moreover, in the literature, building a better environment seems to be a public good; provision of which is a task that is hardly undertaken by private sector; it is mainly non-private and this responsibility falls on governments. Mobilization of financings toward related institutions will be easier if financial markets are developed (Tamazian and Rao, 2010).

According to Schumpeterian economics, financial instruments facilitate development. Technological innovation involves various levels of risks which cannot successfully be implemented unless we can adopt risk sharing measures. These measures are easily expanded by instruments provided by financial development (Tadesse, 2005). Some researchers go further and emphasize on the role of financial innovation in the development process. Financial development, in association with financial innovation in an asymmetric information setting, by reducing frauds through recognizing good entrepreneurs from bad ones, provide higher levels of economic growth and efficiency, which can have positive effects on environment. Of course, financial instruments have a crucial role in removing credit constraints. However, financing firms and consumers in case of credit constraints is severely influenced by good governance. Good governance and related regulations by giving financial preferences and privileges to eco- friendly projects, firms, industries and consumers can help to reduce CO_2 emissions (Claessens and Feijen, 2007).

It should also be noted that financial development motivates economic growth which in an attempt to reaching higher levels of living standards and development reduces pollutants especially CO_2 emissions (Grossman and Krueger ,1995).

2.1.2 Why a Nonlinear Relationship?

The above arguments refer to positive and negative effects on the pollutants that financial development and the resulting economic activity can have. As the economy moves to higher levels of development some effects outweigh others so that depending on the level of development there can be a nonlinear relation among variables. What is the theoretical rationale for the nonlinear relation? Grossman and Krueger (1995), following the famous Kuznets (1955) inequality curve state that in early stages of economic development, environmental degradation increases up to a certain level of income (called the turning point), and thereafter decreases. Therefore, an inverted-U shape curve between per capita income and pollutant index was assumed, which later became known as EKC, see Shafik and Bandyopadhyay (1992). Several arguments advocate this nonlinear functional form. One argument indicates that environmental quality is a normal good with an income elasticity of demand greater than zero (and perhaps even greater than one). Thus with increases in income there can be greater and less than proportional increases in demand. Beckerman (1992) has based his nonlinear relation between variables on this ground.

As a second argument, we can refer to the role of governments. Neumayer (2003) and Copeland and Taylor (2004), conclude that government policies about environment is not implemented linearly: with increasing levels of economic growth, states can increasingly subsidize eco-friendly activities via more favorable institutional capacity.

Demographic changes brought about by economic growth make the third rationale for specifying a nonlinear relation among pollutants and relevant variables: Grossman and Kreuger (1993) argue that with increasing levels of development, population growth declines and therefore there will be less population pressures on environment.

Grossman and Kreuger (1995), in yet another study refer to three channels, which strengthen the probability of the existence of a nonlinear relation scale, combination and technical effects. This fourth argument goes as follows: scale effects refer to the point that with increasing levels of the scale of the economic activities, pollutants increase. Combination effect refers to the fact that with economic growth, the economy experiences profound structural transformations, which at first hinges upon natural resources and favors manufacturing industries thus increasing pollutants .Technical effect refers to the adoption of energy efficient techniques in higher levels of development which, reduce pollutants .These three effects can produce a nonlinear relationship between pollutants and (financial) development .As the economy moves from low to high levels of development, structural change in the form of higher share of industrial sector and lower share of agricultural sector takes place which increases pollutants .However ,in higher levels of development ,the share of services sector increases at the expense of industrial sector and consequently pollutants decreases.

Although the above arguments and specially those of Grossman and Kreuger may lead us to an EKC inverted-U shape for the nonlinear relationship, some authors such as Koop, and Tole (1999), and Torras and Boyce (1998), emphasize on more general nonlinear functional forms. Neumayer (2003), with this reasoning, concludes that there can be an N-shape relationship among variables. However, these arguments support the view that the functional form of relations in which pollutants are dependent variable can have several nonlinear forms.

2.2 Empirical Literature

The empirical relationship among environmental pollution, economic growth and financial development has been the subject matter of many studies in the past two decades. Although many of the studies mentioned above have both theoretical and empirical aspects (which we especially emphasized on the theoretical relevance of them in the above), we can now place more emphasis on the empirical aspect of subject. Most of the research work in this field has been in the framework of EKC. One can classify the research work in this field into categories according to the approach and technique used, the type of the data, the geographical scope (regions and countries) covered and also the results achieved (as for the sign and the significance of the effects).

With regard to the approach used in the research, some studies use aggregate growth models in equilibrium settings (such as DSGE, CGE etc.) for inspecting the relationship among economic and financial development and energy consumption and pollutants (Jorgenson and Wilcoxen, 1993). Some studies have econometric approach, which can be classified according to the technique used as follows. Some of these studies have used financial development as a potential factor affecting CO2 emission (Ang, 2007, 2008; Halicioglu, 2009; and Shahbaz et al., 2012). Yet another group of studies use a multivariate system-wide approach to study the relationship among variables. Some subset of these research work use time series techniques such as VAR, VECM etc. (Shahbaz et al. , 2013).

As for the results achieved, the first group of the studies indicate that higher levels of financial development and economic activities lead to higher levels of production, trade and consumption which in turn lead to higher burden on the ecology and hence producing more pollutants (Georgescu-Roegen, 1971).The second group of research work, by emphasizing on the World Bank's "win-win" framework of the game among economic agents indicate that as the economic activities increase, the maintenance and improvements in environment would become important, since higher levels of financial development and sustainable growth is achievable by a clean environment (Meadows et al., 1992). The third category of studies document that there is no significant relationship between pollutants and financial and economic variables (Panayotou, 1997).

As for the type of the data used, econometric studies use the following three data types: cross sectional, time series and panel data. With regard to the studies using cross-sectional techniques and data set, Talukdar and Mesner (2001), examine the effects of financial development and private investment on CO2 emissions in 44 countries for the period 1987-95. They conclude that both variables have positive effects on CO2 emissions. Claessens and Feijen (2007) pay attention to the interaction of governance and financial development on CO2 emissions and conclude that financial development by motivating firms' activities to use efficient technologies in energy consumption reduces pollutants.

As for the studies using time series techniques concentrating on one country, Mohamed Amine Boutabba (2013), examines the effects of financial development, income, energy use and trade on CO2 emissions for India. His estimated equation is an EKC, which regresses CO2 emissions on the above variables. Data set includes the time series of the variables for the period 1970-2008.The technique used is ARDL and the concentration is on the causality test of relations among variables. The causality test indicates that there is a unidirectional Granger causality from per capita real income, energy consumption and financial development to CO2emissions. Regarding the effect of financial development, there is the evidence of a positive and significant effect on CO2 emissions in the long run. Ozturk and Acaravci (2013), examine the causality relationships among financial development, economic growth, openness, energy consumption and carbon emission in Turkey for the period 1960-2007.Their results indicate that there is one long run relationship among the variables. In their study, financial development has no significant long run effect on carbon emission.

With regard to panel data studies, Aslanidis and Iranzo (2009) using 77 non-OECD countries data for the period 1971−1997 with variables per capita income and carbon dioxide (CO2) emission estimated a PSTR. They found no evidence of EKC. Sadorsky (2010) examines the effects of indicators of financial development on the energy consumption for 22 countries of emerging economies. He found a significant and positive relationship between financial development and energy use. Tamazian and Rao (2010) by using a dynamic panel data model and generalized method of moments (GMM) studied the effects of financial, economic and institutional development on CO2 emissions in 24 countries in transition for the period 1992-2004.They conclude that these factors reduce CO2 emissions. They confirm the existence of EKC for those countries. Narayan and Narayan (2010) studied 43 developing countries during 1980–2004.The variables used are per capita CO2 emissions and per capita GDP. Using Pedroni panel cointegration tests and panel VECM, they found that income elasticity in the long run was smaller than the short run only in two panels, and EKC exists in these two panels. Farhani and Rejeb (2012) by focusing on the 15 MENA countries data during 1973–2008 and by using energy consumption, GDP and CO2 emissions as their variables and panel cointegration and panel causality test as their method conclude that there is no causal link between GDP and energy consumption and between CO2 emissions and energy consumption in the short run. However, in the long run, there is a unidirectional causality running from GDP and CO2 emissions to energy consumption. Joe-Ming Chiu (2012) used the data for 52 developing countries in 1972−2003 period. The variables are arable land area, real GDP per capita, rural population density, trade openness, and political freedom. The result is that a PSTR-EKC relationship exists for deforestation. Also there is strong threshold effect between deforestation and GDP. Duarte et al. (2013) using data for 65 countries 1962−2008 with variables water use per capita, income per capita, precipitation and political freedom and using PSTR technique found an inverted-U relationship, with a marked downward limb that dominates the nexus. Chen and

Huang (2014) studied the data for 36 countries during 1985−2012 period. Their variables were CO2 per capita and GDP per capita, oil consumption, natural gas consumption, and coal consumption. The technique used was PSTR regime switching model. They conclude that there is a significant effect of oil consumption, natural gas consumption, and coal consumption on pollutants. Lee (2014) by concentrating on OECD countries and using PSTR technique concludes that the relation among CO2 emissions, financial development, economic growth and trade openness is nonlinear. While his study validates the EKC framework for the countries under study, it is emphasized that trade openness and the volume of foreign trade have negative effects on CO2 emission.

With respect to studies using panel data techniques, Basarir and Cakir (2015) study the casual relationship between tourism, energy consumptions, financial development, and carbon emissions in Turkey and four European countries France, Italy, Spain and Greece which are Turkish main competitors in tourism. For the panel, as a whole, there are statistically significant feedback effects between the variables: one per cent increase in energy consumption will raise CO2 emission by 3.02 %, a one percent increase in the financial development will decrease CO2 emission by 0.12 % and also one percentage increase in tourist arrivals will decrease CO2 emission by 0.11 %. According to the causality tests there is a uni-directional causal relationship between the tourist arrivals and financial development. And also there is a bi-directional causality relationship between CO2 emission, financial development, and energy.

Saidi and Hammami (2015) using a dynamic panel data model analyzed the effect of economic growth and CO2 emissions on energy consumption for a panel of 58 countries for the period 1990–2012. Their model was estimated by means of the GMM with variables energy consumption per capita, GDP per capita, CO2 emissions per capita, financial development, capital stock and population. Similar analysis was implemented for three regional panels: Europe and North Asia, Latin America and Caribbean, and Sub Saharan, North African and Middle East. The results indicate significant positive effect of CO2 emissions and economic growth on energy consumption for the panels. Heidari et al. (2015) studied the trends of pollution in the five ASEAN countries during 1980–2008. Variables were CO2 emissions economic growth, and energy consumption. His PSTR specification supports the EKC hypothesis. Kasman and Duman (2015) studied the data of 15 new EU members during the period 1992–2010. The variables are per capita total primary energy consumption, per capita CO2 emissions, per capita GDP, trade openness, and the share of urban population. They applied panel cointegration tests by Kao, Pedroni, Westerlund and panel-based error correction model by which EKC hypothesis was supported. They showed there is short-run unidirectional panel causality running from energy consumption, trade openness and urbanization to CO2 emissions. Also, they demonstrated the existence of a long-run causal relationship. Al-mulali et al. (2015) focusing on 18 Latin America and Caribbean countries for the period 1980−2010 and using variables GDP, electricity consumption, financial development and CO2 with VECM Granger causality test, Kao panel cointegration test and FMOLS found evidence of EKC between GDP and CO2. It is shown that financial development has a negative long run effect. Energy consumption had no long-run effect on CO2. Bidirectional causality exists between CO2 and all the variables.

In the study of Salahuddin et al. (2015), six Persian Gulf Cooperation Council (GCC) countries during the period 1980–2012 are studied. They examined the trends of CO2 emissions, economic growth, electricity consumption and financial development using DOLS, dynamic fixed effects, FMOLS and panel Granger causality tests. They concluded that electricity consumption and economic growth have a positive long run relationship with CO2 emissions while financial development had a negative effect. Bidirectional causality exists between economic growth and CO2 emissions. Also, there exists unidirectional causality running from electricity consumption. No causal link exists between financial development and CO2. Magazzino (2016) focused on 10 Middle East countries during the period 1971–2006. He used CO2 emissions, economic growth, and energy use in the Panel VAR approach. For 6 countries, the effect of CO2 emissions on growth is found to be negative and CO2 emissions are driven by energy consumption. CO2 emissions and energy have no impact on growth in the other 4 four countries.

Ahmed et al. (2017) studied 106 countries energy consumption per capita growth, CO2 emissions per capita growth and real GDP per capita growth for the period 1971–2011. According to their Panel VAR, EKC hypothesis is not supported. Also there exists heterogeneous effect of various types of energy consumption and there is bidirectional causality between total economic growth and energy consumption. Kais and Ben Mobarek (2017) examine the data for three North African countries in the period 1980–2012.Variables under study are energy consumption, CO2 emissions and economic growth. Using panel co-integration test and panel VECM it is shown that there is a unidirectional relationship of causality running from economic growth to CO2 and also from energy consumption to CO2 emissions. Ahmed et al. (2017) studied five South Asian countries for the period 1971–2013. Series considered are CO2 emission, energy consumption, income, trade openness and population and the techniques used are Pedroni- Kao- and Johansen-Fisher-panel cointegration tests. It is shown that in the long run, energy consumption, trade openness and population has negative impact on CO2 and there is a unidirectional causality from them to CO2. Uddin et al. (2017) considered 27 highest emitting countries during 1991−2012. By using real income, financial development, trade openness, ecological footprint (EF) as the variables of the study and by applying Pedroni co-integration tests, DOLS and FMOLS methods, a long run relationship is found. Also, it is found that EF and real income share have positive and significant long run relationship. Trade openness has negative effect on EF and financial development reduces EF. Charfeddine and Mrabet (2017) studied 15 MENA countries during 1975–2007 and concentrate on EF, energy-use, real GDP, life expectancy at birth, fertility rate and political institutional index. They used Pedroni panel cointegration test and Granger panel VECM thereby the EKC hypothesis is validated in all countries and also oil-exporting countries but not in non-oil exporting countries. Long term effect of urbanization, life expectancy at birth and fertility rate is found. Energy use worsens ecological footprint. Bidirectional causality found between EF, GDP and energy-use variables. Shahbaz et al. (2017) examined the data for 105 countries during 1980–2014. Trade openness, CO2 emissions and economic growth are used. Pedroni and Westerlund panel cointegration tests and panel VECM model indicated that the three variables are cointegrated. Trade openness worsens environmental quality. There is feedback causality between trade openness and CO2 at the global level and for middle income countries but unidirectional causality from trade openness to CO2 for the high income and low income countries.

3. Material

3.1 The Model: PSTR (Panel Smooth Transition Regression)

In this section, a brief overview of the technique is introduced. The basic PSTR model by using panel data set with two extreme regimes is defined as follows:

$$y_{it}=\mu_i+\beta_0' x_{it} + \beta_1' x_{it} g(q_{it};\gamma,c)+u_{it}\ , \tag{1}$$

for i= 1, . . . , N, and t = 1, . . . , T, where N and T denote the cross-section and time dimensions of the panel, respectively. The endogenous variable yit is a scalar, xit is a K-dimensional vector of time-varying independent variables, μ_i represents the fixed individual effects, and u_{it} are the disturbances. Transition function $g(q_{it};\gamma,c)$ is a continuous function of the observable variable qit and is normalized to be bounded between 0 and 1, and these extreme values have regression coefficients β_0 and $\beta_0 + \beta_1$. More generally, the value of qit determines the value of $g(q_{it};\gamma,c)$ and thus the effective regression coefficients $\beta_0' + \beta_1' g(q_{it};\gamma,c)$ for individual i at time t. We use the following logistic specification,

$$g(q_{it};\gamma,c)=(1+\exp(-\gamma \textstyle\prod_{j=1}^{m}(q_{it}-c_j))^{-1}\ , \tag{2}$$

with $\gamma > 0$,
and $c_1 \le c_2 \le \cdots \le c_m$,

where c = (c_1, . . . , cm)' is an m-dimensional vector of location parameters and the slope parameter determines the smoothness of the transitions. The restraints $\gamma > 0$ and $c_1 \le c_2 \le \cdots \le c_m$ are imposed for identification purposes. In practice, it is usually sufficient to consider m = 1 or m = 2, as these values allow for commonly encountered types of variation in the parameters. For m =

1, the model have two extreme regimes associated with low and high values of qit with a single monotonic transition of the coefficients from β_0 to $\beta_0 + \beta_1$ as qit increases, where the change is centered around c1.When $\gamma \to \infty$,g(q_{it};γ,c) becomes an indicator function I[qit> c1], defined as I[B] = 1when the event B occurs and 0 otherwise. In that case, the PSTR model in (1) reduces to the two-regime panel threshold model of Hansen (1999). For m = 2, the transition function has its minimum at $(c_1 + c_2)/2$ and attains the value 1 both at low and high values of qit. When $\gamma \to \infty$the model becomes a three-regime threshold model whose outer regimes are identical and different from the middle regime. In general, when m > 1 and $\gamma \to \infty$, the number of distinct regimes remains two, with the transition function switching back and forth between zero and one at c_1, . . . , cm. Finally, for any value of m the transition function becomes constant when $\gamma \to 0$, in which case the model collapses into a homogenous or linear panel regression model with fixed effects. A generalization of the PSTR model to allow for more than two different regimes is the additive model, as follows,

$$y_{it}=\mu_i+\beta_0' x_{it} + \sum_{j=1}^{r} \beta_j' x_{it} g_j\left(q_{it}^{j}; \gamma, c_j\right) + u_{it} \ , \qquad (3)$$

where the transition functions

$$g_j(q_{it}^{j};\gamma,c_j), \quad j=1,2,\dots,r \qquad (4)$$

are of the logistic type. If m = 1, qit=qitj and $\gamma_j \to 0$ for all j = 1,…, r, the model becomes a PTR model with r + 1 regimes. Consequently, the additive PSTR model can be viewed as a generalization of the multiple regime panel threshold models in Hansen (1999). When the largest model that one is willing to consider is a two-regime PSTR model with r = 1 and m = 1 or m = 2, the most recent model plays an important role in the evaluation of the estimated model. In particular, the multiple regime model is an obvious alternative in diagnostic tests of no remaining heterogeneity.

3.2 The Variables

Table 1 contains the name, notation and the description of the variables used in the model.

Table 1. Name, Description and Notation of the variables

Variables	Description	An Indicator for	Notation
CO2	Measured in Metric tons per capita	Pollutants	LC
Real GDP	Measured in US Dollar	Economic performance	LY
M	Ratio of private Sector credit to GDP	Financial development	M
Population	Total population in million persons	Social factors	LPOP
Energy use	kg of equivalent oil per capita	Total energy used	euse

Descriptive statistics of the series are presented in table 2.

Table 2. Descriptive statistics of the variables

	CO2	Real GDP	M	Population	Energy use
Mean	328276.7	2.04E+11	32.47458	1.15E+08	1103.717
Median	104713.0	6.17E+10	25.34335	31727338	870.3788
Maximum	8767878.	6.10E+12	175.7381	1.34E+09	2979.074
Minimum	634.3910	5.49E+08	10.08290	1848873.	305.1273
Std. Dev.	919812.5	5.05E+11	22.80428	2.83E+08	623.1450
Scenes	5.645335	6.966211	3.700134	3.381154	1.158323
Kurtosis	39.36774	65.33516	18.31859	12.95046	3.482908
Jarque-Bera	34318.84	96554.91	6849.683	3425.525	132.5344
Probability	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	1.86E+08	1.16E+14	18445.56	6.51E+10	626911.0
Sum Sq. Dev.	4.80E+14	1.44E+26	294859.8	4.53E+19	2.20E+08

Where possible, logarithmic form of the series are used. It should be noted that using the per capita data in the model pose questions about the inclusion of the population in the model. As a matter of fact, it is the density of population (e.g. population per square kilometer) that can affect per capita pollution which due to the fixed nature of geographical area of the countries over time, upon taking logarithm from the variables, they are subtracted from fixed effects of the countries. Therefore, the intercepts capture the effect of density and slop coefficients do not change. The data are for the period 1970-2013 and reported from World Bank data sets (data.worldbank.org/indicator).

3.3 The Countries

Our study covers 16 countries including Iran and some countries of BRIC such as India in middle income group countries. The countries in the sample are as follows: Algeria, Argentina, Brazil, China, Colombia, Costa Rica, Ecuador, India, Iran, Mexico, Paraguay, South Africa, Thailand, Tunisia, Turkey, and Venezuela.

3.4 Stationarity of the Data

With regard to the time series dimension of the data, tests of the stationarity of the series are in order. In this regard, unit root tests of Levin, Lin and Chu t, Im, Pesaran and Shin W, Augmented Dickey Fuller (ADF) Fisher-type Chi-square and Philips Perron (PP) Fisher-type Chi-square are performed. The null hypothesis is "The existence of unit root in the series". The results of the tests reject the null hypothesis and all of the series for the sample period are stationary. The results are presented in table 3, which for the sake of brevity only the significance level of the tests are reported.

Table 3. Significance level (Prob.) for various unit root tests

	LC	LPOP	M	LY	euse
Null: Unit root (common unit root)					
Levin, Lin , Chu t-statistic	0.001	0.000	0.001	0.000	0.039
Null: Unit root (individual unit root)					
Im, Pesaran and Shin W-statistic	0.003	0.005	0.000	0.000	0.031
ADF - Fisher Chi-square	0.001	0.000	0.000	0.000	0.014
PP - Fisher Chi-square	0.000	0.012	0.000	0.000	0.009

3.5 The Specification of the Model

The dependent variable is CO2 emission as defined above. The variables GDP, population and energy use are considered as the explanatory variables of the model. All of the three variables enter in both the linear and nonlinear parts of the model. At first, financial development was entered as an explanatory variable alongside the other three variables but its coefficient was not significant. To capture the interactive effects of financial development and also to estimate its threshold effect, the ratio of private sector credit to GDP is entered as threshold variable. It is expected that financial development affect CO2 emission nonlinearly and that it can be considered as a conditioning variable i.e. the effects of the other explanatory variables are conditional on it. In other words, depending on the level of financial development their effects differ. The assumed model has a two-regime of high and low CO2 emission with $r = 1$ and $m = 1$ specification.

4. Estimation Results

Before estimating the EKC-PSTR model, it is necessary to test for the possibility of nonlinear relation between CO2 emission and the relevant explanatory variables. To this end a first round linear fixed effects panel data model is run. The residuals are used for testing nonlinear relation. In this regression, residuals are regressed on nonlinear terms which are made from multiplying explanatory variables by the threshold variable. Threshold variable is a measure of financial development calculated as the ratio of private credit to GDP. Coefficients C (211), C (322) and C (344) are the estimated parameters of interaction terms of threshold variable with GDP, population and energy use. Wald statistic for the null hypothesis of no nonlinear relation in the following form: H0:There is a nonlinear dependence of the CO2 emissions on the variables

is computed, and the results are shown in table 4.

Table 4. Test for the existence of nonlinear relation

Wald Test			
Statistics	Value	d.f.	prob.(sig.)
F- Statisic	25.77	(634,3)	0.000
Chi-square Statistic	77.32	3	0.000

The null hypothesis is rejected, hence fitting the nonlinear regression is feasible. Therefore, in the second round of estimation the fixed effects EKC-PSTR model was fitted to the data. In the first round of estimation, the quadratic term of output level and also financial development variable were not significant (a la Aslanidis and Iranzo (2009), Ahmed et al. (2017)). Thus after dropping the quadratic term, the model was re-estimated. The results are as follows (table 5).

The estimation is implemented by a program written by the author. The method assumes one shift parameter, one threshold and one location parameter. Also the fixed effects for countries are as follows (table 6).

D1 to D16 refers to dummy variables associated with countries in fixed effects method. They belong to countries: Algeria, Argentina, Brazil, China, Colombia, Costa Rica, Ecuador, Iran, Mexico, Paraguay, South Africa, Thailand, Tunisia, Turkey, Venezuela and India, respectively.

After estimating the PSTR model we must test for the possible remaining nonlinear effects. The null hypothesis of no remaining nonlinear effect i.e.

HO: There is a further nonlinear relationship (remaining in the residuals of the model)

is not rejected because the F and chi-square statistics are not significant. The results are as follows (table 7).

Table 5. Panel Smooth Transition Regression Estimation Results: Panel Nonlinear Least Squares- White Variance-Covariance

variable		coefficient	standard error	t-statistic	prob.
linear part	constant	-1.52	0.190	-7.99	0.000
	Gross national product	0.03	.005	6.13	0.000
	population	0.12	0.063	2.03	0.042
	energy use	.001	.0001	7.01	0.000
Nonlinear part	Gross national product	.037	.0065	5.7	0.000
	population	-0.81	0.073	-11.12	0.000
	energy use	-.0008	0.00014	-5.734	0.000
Financial development	threshold	33.99	60.5	52.08	0.000
	gamma parameter	-0.63	0.116	-5.4	0.000

Table 6. Fixed Effects Coefficient for the countries

country	Coefficient	t-statistic	prob
Algeria	133.1	11.1	00000
Argentina	140.24	11.7	00000
Brazil	147.54	12.31	00000
China	176.31	14.71	00000
Colombia	129.86	10.83	00000
Costa Rica	97.96	8.17	00000
Ecuador	116.22	9.69	00000
Iran	147.83	12.33	00000
Mexico	150.81	12.58	00000
Paraguay	92.07	7.68	00000
South Africa	151.26	12.62	00000
Thailand	135.59	11.31	00000
Tunisia	113.03	9.43	00000
Turkey	141.07	11.77	00000
Venezuela	139.33	11.62	00000
India	158.95	13.26	00000

Table 7. Test of remaining nonlinear effect

Wald Test			
Statistics	**Value**	**d.f.**	**prob.(sig.)**
F- Statistic	**1.29**	**(634,3)**	**.2737**
Chi-square Statistic	**3.89**	**3**	**.2727**

Hence, the estimated model captures the systematic part of the effects on CO2 emission and there is no need to take more elements of nonlinearity including more number of threshold terms.

5. Discussion

It can be inferred from nonlinear PSTR estimation results from table 4 that financial development has an overall positive significant effect on CO2 emission. This is because Fig.6 shows the logistic part of the nonlinear section of the relation.

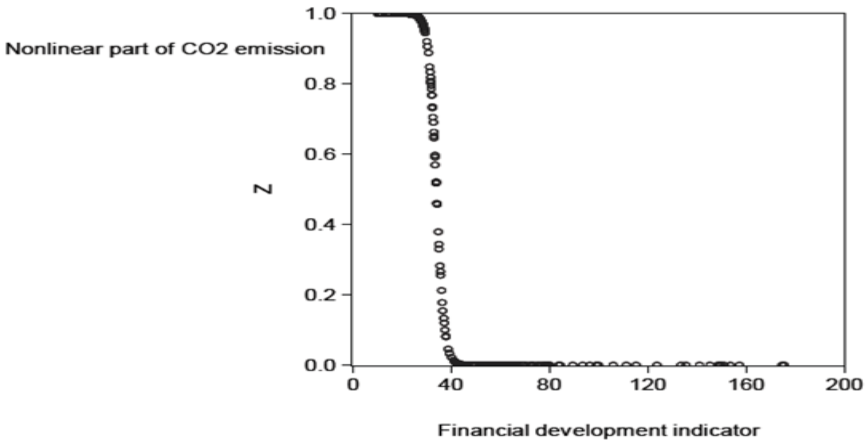

Fig.6. The nonlinear effect of financial development on CO2 emission

The effect of financial development on the nonlinear part (which has negative coefficient for some variables) declines with higher levels of financial development, hence the overall of financial development is positive. The elasticity of CO2 emission with respect to financial development index is 0.07. The threshold for this variable is 34 %, i.e. the greatest rate of decline in the nonlinear part of the estimated equation for the private credit to GDP ratio is 34%. Up to this point, the effect of the nonlinear part decreases rapidly (the effect of financial development on the increase of pollution rises at an increasing rate) after which the intensity of the decrease reduces (the effect of financial development on the increase of pollution, declines). Confidence interval for the threshold of financial development between two extreme regimes at 10, 5 and 1 % levels of significance (90, 95 and 99 % of confidence) coefficients are reported in table 8:

Table 8. Confidence (CI) for various confidence levels

Threshold	90%	95%	99%
Financial Development Index	(32.92,35.07)	(32.71,35.27)	(32.31,35.68)

Three explanatory variables GDP, population and energy use have positive and significant effects in linear part of the model. Population ceteris paribus have the greatest coefficient for variables affecting pollution. As to the overall effects of variable, we need total differentiation of the relation with respect to the variables. These marginal effects at average level of financial development for energy use and GDP are still positive. However, at higher levels of financial development in the sample the effect of energy use (due to the negative sign of the coefficient in nonlinear part) intensifies. This shows that the countries under study have had few measures to shift toward fuel efficient technologies. However, the effect of GDP on pollutions becomes weaker at higher levels of financial development. This means that there has been a general move toward eco-friendly standards in overall production of these economies. The marginal effects of energy use and GDP in the form of elasticity at mean value of the variables in the sample are 5.2121e-04 and 5.05, respectively. The marginal effects for population at average level of financial development are negative. That is at average level of financial development index, population has negative effect on pollution, however the higher the level of financial development the effect of population on the pollution intensifies. This can be due to low quality of population resulted from insufficient levels of human capital formation in the form of better education financed by financial markets.

6. Concluding Remarks

In this paper, the PSTR technique as a nonlinear regression is applied to a panel-data set for 16 countries (including some countries of BRIC and Iran) during the period 1970-2013. We found that output level has a positive significant effect on CO2 emission but its effects at higher levels of financial development, decrease (coefficient ranges from .07 to .03 in low and high levels of financial development regimes). Also, it is found that energy use has a positive significant effect on CO2 emission and its effects at higher levels of financial development increase (coefficient ranges from .0002 to .001 in low and high levels of financial development regimes). The effect of population on CO2 emission at higher levels of financial development, increase (coefficient ranges from -.684 to .128 in low and high levels of financial development regimes). As to the effect of financial development, it has a positive significant effect on pollution with a threshold level of 34 percent for financial development index (private credit to GDP ratio) .The results are compatible with several studies, for example with respect to energy use and GDP Salahuddin et al. (2015), Kais and Ben Mbarek (2017), Ahmed et al. (2017), with respect to population Ahmed et al. (2017) and with respect to financial development Sadorsky (2010), Dasgupta et al. (2001), Jensen (1996), Kumbaroglu et al. (2008), Halicioglu (2009), Jalil and Feridun (2010) report similar results.

We have followed the tradition of typical empirical studies which approximates financial development with either one of two measures of financial depth i.e. the ratio of private credit to GDP or stock market capitalization to GDP. However, these indicators do not take into account the complex multidimensional nature of financial development. . To examine the robustness of the results, the model was run using other indicators of financial development mentioned in the literature. One of these indicators is "the New Broad-based Index of Financial Development" recently published by IMF (Svirydzenka, 2016). For calculating this index, as a first step, nine indices are created which summarize how developed are the financial institutions and financial markets in terms of their depth, access, and efficiency. These indices are then aggregated into an overall comprehensive index of financial development. With the coverage of 183 countries on annual frequency between 1980 and 2013, the database contains a comprehensive financial index for the countries of our study. The estimates obtained by using these index is very close to those reported above; specifically, the threshold estimated using this broad-based index of financial development is 44 percent which its difference with the that of estimated above is insignificant.

Irrespective of the underlying causes, the implication is that although financial development has a favorable effect on the quality of life, and the model shows evidence of applying eco-friendly technologies and standards in overall production of the relevant economies, there has not been enough measures with respect to employing fuel efficient technologies in energy consumption so that it has had an overall adverse effect on the pollution. Also, financial development should redirect its financing toward human capital to increase the quality of the population able to promote sustainable environment. In this research the model has one threshold with two extreme regimes. Future research in this regard can be pursued in the following lines:

-Instead of a single pollutant i.e. CO2, more comprehensive measures of environmental quality should be considered. One of the most important of these indices is environmental performance index, however, limitations of its data hindered us to use its data in the present study.

-Estimating the effects of the explanatory variables on other pollutants such as halogenated fluorocarbons (HFC), nitrousoxide (N2O), sulphur hexafluoride (SF6) and per fluorocarbons (PFC) and NOX.

-Taking into account more location parameters and threshold parameters. Incorporating control variables which capture the structure of economy, society and cultural factors. Estimation of cross section specific coefficient gives more precise picture of effects.

-Using other indicators for financial development and checking the robustness of the results.

-Limitations on the availability of data impose an important restriction in the research which can be removed by richer data set.

-Having a closer look at dynamic effects of variables in short and long run.

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