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Environmental Kuznets Curve and Economic Growth: The Role of Institutional Quality and Distributional Heterogeneity Revisited

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Abstract

We re-examine the frequently observed inverted U-shaped relationship between income and environmental quality (Environmental-Kuznets-Curve, EKC) by introducing the roles of institutional quality and distributional heterogeneity. A panel quantile regression of 127 economies run over a period of four decades demonstrates that once endogeneity bias is corrected and heterogeneity in the effects of income and institutional quality is introduced, EKC tends to disappear at higher quantiles of emission but proves its existence at lower quantiles. The non-uniqueness of EKC is also confirmed by robustness checks where various instruments for institutional quality as well as an alternative measure of emission are introduced.

Key Words: Income and environment; Endogeneity bias; Institutional heterogeneity; Instrumental variable; Panel quantile regression.

JEL Code: Q56, C21, C23

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1 Introduction

Theoretical and empirical research examining the effect of economic development on environment - dubbed as the environmental Kuznets curve (EKC)[1,2] - have concluded the following: *(i)* in many instances, they depict an (inverted) U shaped relationship[3], *(ii)* the strength of this relation tends to vary along heterogeneous development pathways, and *(iii)* estimation methods are very important in realizing the theoretical predictions. With respect to *(i)* and *(ii)*, there have been extensive discussions of the theoretical underpinnings on why EKC would exist, or would not (for profound surveys, see Dinda, 2004; Bartz and Kelly, 2008; Constantini and Martini, 2010; Flores et al., 2014). With respect to *(iii)*, an astounding growth of empirical research has emerged in recent years stressing that estimation methods, sample selection (i.e., cross section and panel, length of the sample, etc) and variable selections are major determinants of income-environment relationship. Notable among them are Flores, et al. (2014) and Lin and Liscow (2012). These authors have atitempted in tackling two major limitations of the estimation approaches with regard to EKC, viz., estimation at the mean and the presence of endogeneity bias. Employing panel quantile regression approach for US state level data on SO_x and NO_2 pollutants, Flores et al. (2014) demonstrate that income-environmental degradation relationship is sensitive to the presence of outliers. Similarly, Lin and Liscow (2012) employ IV regression method for water quality-income data and find that with the treatment of endogeneity bias, EKC tends to disappear for many indicators of water pollutants. However, there is sparse literature - to the knowledge of the authors - that solves both problems simultaneously. The primary focus of this paper is to bridge this void in the literature.

A major emphasis of this paper is also on a rigorous study of the role of 'institution' in EKC - a notable weakness of the empirical literature on the subject till date. Indeed, there is robust argument in the literature suggesting that institutional quality can significantly affect environmental performance (e.g., Eriksson and Persson, 2003, 2013; Drosdowski, 2006). The leading idea of this strand of literature is that with an improvement in institutional quality, the pressure on environmental performance declines, thereby improving the overall environmental quality. A negative effect of institutional quality improvement on the growth of pollution can also be observed where it can be argued that quality improvement in institution purges a policy effect on pollution growth so that year-to-year basis of growth of pollution would decline as a country continues to move on democratic ladder or experiences a sharp transition from autocracy to democracy. On the empirical front, there has been some exceptional research in directly examining the effect of some measures of 'institution' and environmental performance. For instance, in Farzin and Bond (2006), Lin and Liscow (2012), and Fredriksson

[1] As initially suggested by Grossman and Krueger (1995), it is graphically represented by an inverted U shape relationship: increases in affluence from low to moderate levels produces increased environmental stress but further increases eventually leads to a tipping point after which further affluence reduces environmental stress.

[2] A conventional measure of economic development is per capita income. However, in some recent research (e.g., Constantini and Martini, 2010), income factor in EKC is replaced with UNDP's Human Development Indicator, assumed to be a more comprehensive measure of development. Similarly, while the conventional indicators of environmental quality are atmospheric emissions - such as CO_2 emissions, SO_2 or NO_2 levels - and water quality, recent research uses World Bank's Genuine Savings index as a replacement for environmental degradation (Constantini and Martini, 2010).

[3] Ekin (1997) argued that unequivocal evidence for an EKC relationship is very scant and that there are important indicators which show a monotonically increasing relationship

and Neumayer (2013), it is concluded that political institutions have significant effects on environmental degradation.[4] A major limitation of these research concerns either non-treatment or insufficient treatment of the role of political institution in minimizing possible endogeneity bias that may arise from the simultaneous presence of income and political institution in EKC regression. With improvement in estimation methods even if the EKC is established or shown to disappear at various points of the distribution, the centrality of institution needs to be checked within the modified framework for the simple reason that environmental performances have been shown in the developing literature to be directly influenced by the quality of governance.

Thus, in our conceptual setting of EKC we assign a significant role to institutional quality, which through its effect on income growth will indirectly determine the dynamic movement of pollution. At the core of our framework lies the fact that the total effect of income on pollution is a combination of *direct* effect of income on pollution and *indirect* effect of income on pollution via changes in institutional quality. However, the empirical literature is replete with evidence where it is shown that income and institutional qualities are endogenously determined, hence simultaneous use of both in EKC regression would result in endogeneity bias, which must be treated to derive meaningful inference of the effect of income on environment.

In view of the above, our study addresses the two issues that have been identified but not sufficiently analyzed in earlier studies. First, we treat endogeneity bias that is likely to arise in EKC with robust use of instruments of institutions, and second, we examine the uniqueness and existence of EKC at various quantiles of emission distribution. Our approach is unique and probably the first in this stream of literature as it combines both IV and quantile regression within a single estimation framework and studies the existence and uniqueness of EKC over the entire distribution of emissions per capita. It can be argued that even when both theory and empirics find - using conventional mean-based estimation methods - that a quadratic form of income is linked to environmental performance (U or inverted U), there is no guarantee that shape will continue to remain unique or even exist over the entire distribution of pollution.[5]. Undoubtedly, the role of heterogeneity is seen to be as much important in estimation as finding the true functional form mainly because the response of environment to conditional income variation (via institutional quality) may change pattern from low quantile of environmental quality to median and then to high quantile. It is necessary therefore to move beyond mean-based estimation procedures.

Following Koenker (2004) and subsequent research, it is well-known that the conventional mean-based estimations only reflects the average response of the dependent variable due to the changes in the control variables over time. In the specific case of income-environmental quality relationship, the mean-based estimation would then imply that the coefficient corresponding to the regression of environmental quality on income indicates only how a unit change in income beget an 'average' of environmental quality. This procedure, while is very popular among empirical researchers, actually averages out the specific information that may contain in different parts of the distribution of environmental quality. It is possible that a

[4]See Cole, 2007; Lin and Liscow, 2012; Fredriksson and Neumayer, 2013. For instance, in Cole (2007), corruption is found to be have a large negative indirect effects on per capita emissions (Cole, 2007). In Fredriksson and Neumayer (2013) and Lin and Liscow (2012) it is demonstrated that a rise in quality of political institution can facilitate environmental improvement.

[5]This is indeed one of the major findings of Flores et al., 2014

change in income would beget a large change in pollution dynamics at the lower quantile of its distribution than at the medium and higher quantile. Such heterogeneity in the response of environmental quality may necessitate specific policy interventions than a unique policy would suggest to the entire range of environmental quality distribution. Treatment and investigation of this apparent limitation of the conventional estimation method and theorisation forms the focal point of our paper.

Our model and empirical strategies are primarily related to those papers that have analyzed environmental issues in a dynamic growth optimization framework on the one hand, and panel regression of pollution and growth regression. Our empirical strategy is related to theoretical models of Acemoglu and Robinson (2000), Aidt et al. (2006), Eriksson and Persson (2003), and Drosdowski (2006). With respect to empirical construct, we have drawn motivation from Koenker (2004), Alexander et al. (2011), Flores et al., 2014, and Lin and Liscow (2012). The key innovation of this study is to allow full distributional dynamics to gauge the effect of income and democratisation on pollution and to use instrumental variables to mitigate the problems caused by simultaneity bias and omitted variable bias. Our study is important not only because of its methodology, but also because its results will expand the state of knowledge regarding institution's role in multiple equilibria in environmental performance and the dynamic interlinkage among environmental quality, income, and political institutions.

The remainder of the paper is organized as follows. In Section 2, we provide a synoptic overview of the literature on EKC with a specific focus on estimation related issues. In Section 3, we present stylized facts leading to the construction of our empirical model. Section 4 discusses modelling issues and empirical specification. In Section 5, we present and discuss empirical results. Finally, Section 6 summarizes the main findings with some discussions.

2 Literature

In this section we present a summary review of literature focusing mainly on the divided opinions of the role of institution and income in environmental performance.[6] (Early) empirical studies[7] that led to a massive theoretical and empirical literature in the last two decades broadly fall into two broad strands: (i) one that investigate a wide variety of pollutants at cross-national and/or regional levels claim that an inverted U-shaped pattern between income and pollutants is valid for many *local* and *flow* pollutants. It does not seem to be the rule for *stock* pollutants like CO_2 which generates a monotonically increasing relation between wealth and pollution (see Brock and Taylor (2005), for a survey). However, the observed empirical regularity for stock and flow pollutants at local and/or (cross)-national levels have been shown to be sensitive to the inclusion of structural variables (such as institutional quality), model choice, and estimation methods (see for instance, Lin and Liscow (2012) and Flores et al. (2014), among others). If true, these can lead to problem of synchronization between theoretical predictions and empirical regularity.

(ii) Economic theoretic models which follow predictions of empirics can be mainly di-

[6] Dinda (2004), Constantini and Martini (2010), and Boucekkine et al. (2013), among others, are excellent examples where exhaustive summary, new empirical, and theoretical foundations of EKC are presented.

[7] For instance, Grossman and Krueger (1995)

vided into growth theoretic and game-theoretic (political economy) approaches: Stockey, 1998; Dinda, 2004; Boucekkine et al., 2013 are some of the influential examples of growth theoretic approaches to EKC, whereas Eriksson and Persson (2003, 2013), and Drosdowski (2006) are some of the examples which employ political-economy perspectives to EKC. Constantini and Martini (2010) provide a nice survey of the theoretical and empirical literature of EKC. In what follows next for the purpose of our paper, we will provide a summary of the arguments and inferences - drawing from both growth theory/political-economy perspectives as well as from recent empirical analyses. For ease of arguments, our survey will focus on separate analyses of income-environment, environment-institution, and institution-income relationships.

- **Income and environment**

Among the important theoretical arguments in favour of why EKC would exist, Selden and Song (1994), for instance, argue that environmental quality can be treated as a luxury good such that at the early stage of development, people do not have the luxury to care for environmental quality. However, after reaching a certain critical level of income (where basic needs are met), people tend to care more about environment and are willing to pay for 'environmental management cost'. There is yet another line of thought which emphasizes on the role of education in environmental performance. Given the much observed relationship between education and income, it is possible that along with rising income, educated people become increasingly conscious about the consequences of high economic activity (that is known to contribute significantly to environmental distress). Finally, an instrumental role of political system (that is also empirically found to improve economic performance) can serve as a deterrent to environmental degradation.

Some of the important counterarguments of EKC hypothesis outline (i) the role of smaller elasticity of environmental quality (viz., Flores and Carson, 1995; Kristom and Riera, 1996), (ii) role of political institutions (for instance, Shafik and Bandopadhyay, 1992 find that SO2 concentrations are higher in more democratic countries), and (iii) the role of trade-liberalization (e.g., Jaffe et al., 1995 argue that trade liberaliization increases world production and the transfer of pollution-intensive industries from developed to developing economies. Intuitive survey of income-environmental relationship can be found, among others, in Dinda (2004), Bartz and Kelly (2008), Constantini and Martini (2010), and Flores et al. (2014).

- **Institution and income**

In the literature, competing theoretical models exist which present each of the following possibilities: growth promoting effect of democracy[8], growth inhibiting effect of democracy, and democracy as bearing no independent relationship to development outcomes. Since Barro (1991), conventional belief following a robust empirical research is that democracy is bad for economic growth. China's growth success story with one-party non-democracy is often taken as a complementary evidence in academic and political-economy circle that autocracies can still produce economic giants. A number of leading research lately have also evinced that 'democracy does cause growth'. Che et al. (2013) and Acemoglu et al. (2014) are some of prominent examples in this regard.

[8]Institutional quality and democracy are used synonymously in this paper.

- **Institution and environment**

Democracy is arguably one of the important determinants of environmental performance. There is robust theoretical and empirical evidence in the literature - as reviewed in the preceding paragraphs - suggesting that stronger political institutions (or democracy, broadly) promote economic growth. In the same vein, it is also logical to assume that stronger political institutions can exert both direct and indirect influence on environmental performance. However, conventional EKC literature weakly documents the role of political institution in the existence and/or uniqueness of EKC. There are some interesting research - which we briefly review in the following paragraphs - suggesting why democracy can be both good and bad for environmental performance.

Research which sees instrumental role of democracy in environmental performance hold that under democracy citizens tend to enjoy freedoms and can freely express their opinions on the prevalent life-circumstances they consider adverse. Also due to the freedom of speech, of assembly and of association, citizens may raise issues of environmental concerns and so, may oppose environmental degradation publicly, which through media and demonstrations, influence the public and politicians empowered in free elections. Hence, in democracy it leaves enough room to demand legislative enforcement to protect environment. Moreover, under this regime, increasingly implemented market-based instruments of environmental policy such as green taxes tradeable emission permits create profit responsibilities for enterprises improving environmental effectiveness (Popp, 2003), and arguably this might lead to more minimal-pollution intensive innovation, entailing diffusion and imitation of successful ideas.

Eriksson and Persson (2003, 2013), and Drosdowski (2006), for instance, demonstrate (theoretically) that democratization provided higher marginal utility from consumption relative to marginal utility from better environmental quality, leading to lowering of a pollution standard. Drosdowski (2006) provides intuitive theoretical explanation on whether democratization can be beneficial for environmental quality in the long run.[9]

A robust empirical support to the above theoretical predictions have rather been limited. Fredriksson et al. (2005), for instance, employ a lobby group model and investigate how such groups determines environmental policy in countries differentiated by income paths. It is suggested that environmental lobby groups tend to positively affect the stringency of environmental policy and that political competition tends to raise policy stringency, in particular where citizens? participation in the democratic process is widespread. In a recent research, Lin and Liscow (2012) adopt the widely used EKC framework and discuss, in reference to various environmental quality measures, the effects of political institution within the ambit of income-environment relationship. The authors found evidence of an inverted-U relationship between income and environmental degradation. Political institutions, in general, also were found to exert significant effects on environmental degradation. Flores et al. (2014) employed quantile methodology to explore the robustness of EKC hypothesis and found that conditional mean provide too optimistic estimates and that conditional quantile method suggest that the turning point of the relationship occurs at higher values of income. Similarly, Fredriksson and Neu-

[9]Farzin and Bond, (2006) also demonstrate that factors such as income inequality, age distribution, education, and urbanization may mitigate or exacerbate the net effect of the type of political regime on pollution, depending on the underlying societal preferences and the weights assigned to those preferences by the State.

mayer (2013) argue that democratic capital stock, that is, the duration of democracy over a period of time, has an important and robust effect on climate change policies.

In addition, technological advances related to pollution reduction is restricted giving rise to potential proliferation of environmental problems. In this regard, for instance, Lucas et al. (2002) have shown that the toxic intensity of production tends to be higher in closed economies. In both non-democracies and transitional democracies therefore, (relatively) inflexible regulation tend to preclude ecological improvements and incentive-driven entrepreneurship. Janicke et al. (1997), among others, showed that 'heavy industries strongly represented in the power structures of the communist countries opposed structural changes. On the whole, non-democratic economies are less likely to take part in international agreements directed at limiting pollution or natural degradation of the environment.

3 Data

The observations and the empirical analyses to be presented below are primarily based on data on environmental quality and various measures of democracy. Our measure of environmental quality is per capita carbon emissions (CO_2 per capita emissions) and sulphur dioxide (SO_2) which we have obtained from the World Bank (2012). While CO_2 reflects consumers incentive to keep fossil fuel prices low, as well as the fossil fuel producers lobbying incentive to keep climate change policies weak, SO_2 presents local level pollution dynamics. From global perspective CO_2 represents the amount at stake for CO_2 emitters, and thus their lobbying incentives. However, higher levels of per capita CO_2 likely also imply lower marginal abatement costs (Fredriksson et al., 2007). The emissions are measured in metric tons per capita.

The second variable in the EKC relationship is income, which is measured by real GDP per capita at 2000 PPP. The data has been obtained from the World Bank. The third variable which we also consider as an important determinant of EKC is institutional quality. A variety of measures of institutional quality is used in our paper - led by the development of the concept in the empirical literature. We focus on three well-known measures: (i) *democracy* for which data is publicly available as the revised polity index from the Polity IV database (Marshall and Jaggers, 2009). (ii) Measure of *democratisation* (Papaioannou and Siourousnis, 2008) is used to capture the effect of political transition during the Third Wave of Democratisation. (iii) We also use a number of *executive constraints*, such as bureaucratic quality to capture the effect of political competition. Each measure has important implication for varied roles of institution on income growth and pollution control.

With respect to the first measure, the revised combined Polity score is based on subscores for constraints on the chief executive, the competitiveness of political participation, and the openness and competitiveness of executive recruitment. The Polity2 score ranges from -10 to +10. Higher values denote more democratic institutions. The Polity Code book defines a polity within the range [6,10] as a coherent democracy, one in the range [-10,-6] as a coherent autocracy, and one in the range [-5,5] as an incoherent regime. Formally, it is computed as the difference between a democracy index and an autocracy index, each ranging from 0 to 10.[10]

[10]Fredriksson and Neumayer (2013) use two alternative definitions of democracy. First, they define democracies as those having a positive polity2 score, following Persson and Tabellini (2009). As an alternative, they define

For our application purpose, we assign each government a number between 0 and 10 on each scale based on a set of weighted indicators designed to capture the extent of competitive political participation, institutionalized constraints on executive power and guarantees of civil liberties and political participation. The primary focus of the index is on central government and it notably ignores the extent to which control over economic resources is shared and the interaction between central government and separatist or revolutionary groups. This allows us to estimate six distinct transitions: Autocracy to Partial Democracy, Partial Democracy to Full Democracy, and Autocracy to Full Democracy, as well as the reverse of each. Wherever necessary (due to convenience of comparison among other indicators), the 0-10 scale of democracy has been re-expressed in the scale 0-1, with 10 (full democracy) re-written as 1.

The above also provides the basis for construction of the measure of democratisation (Papaioannou and Siourousnis, 2008) (our second measure) where the focus is on the relevance of regime transition on structural economic outcomes (such as income and pollution, for instance). With this definition we would be able to distinguish between full and partial democratisation episodes and how they affect income and pollution growth. While the detailed description of the data and its usefulness can be found in the authors' paper, it is important to note that a 'full' democratic status is designated to countries where both the Polity indicator is greater than +7 and the Freedom House status characterisation is 'free'. All remaining democratisation countries are denoted as 'partial'.

In addition to the above, other control variables which have been used in our estimation are population density ('000 per square kilometer) ($Density$), trade openness ($Trade$) measured as sum of export and imports as a percentage of national income, capital stock per worker (K), literacy rate (a measure of human capital (H)), rate of inflation (measured by changes in CPI index, $Linfl$), share of industrial output in GDP ($Ind.share$). Population growth (ngr) is calculated as logarithmic difference of total population between time t and $t-1$. While physical capital per worker would directly contribute to income growth and hence would add to environmental pressure through heightened production volume, education (or human capital) would act as a motivator for innovation and contribute directly to economic growth. On the other hand, it can also serve as an indicator of conscience on the part of the citizens not to indulge in pollution-generating activities. Especially, it is expected that educated people can exercise free will and put pressure through voting system for adopting pollution-abating policies. Population density has been included in the regression to capture the broad effect of technological change (e.g., Mishra and Diebolt, 2010). It is argued that high population density encourages innovation through high demand pressure. The use of share of industrial output in GDP should help in understanding the role of industrialisation process (or composition effect), where an economy strongly based on heavy industries should have higher polluting emissions compared to economic systems based on, for instance, agriculture (first development stage) or

democracies as those having a polity2 score above 5 since countries below this threshold (but above -5) are usually categorized as anocracies; combining characteristics from both democratic and autocratic regimes (Plumper and Neumayer, 2010). Furthermore, it is important to note that the Polity IV project also provides the subscores for constraints on the executive, political competition, and executive recruitment. The executive constraints subscore measures the extent of institutional constraints on the decision making powers of chief executives. The score ranges from 1 to 7, with higher values denoting stronger executive constraints. The political competition score measures the degree of institutionalization of political competition and the extent of government restriction on political competition. This score ranges from 1 to 10, with greater values denoting more political competition.

services (advanced development stage) (Hettige et al. 2000). These data have been assembled from the World Development Indicators.

4 Stylized facts

In this section we present two stylized observations depicting the dynamics of relation among pollution, income, and democratisation. The main empirical framework and results to be presented in the next section would be built on the observations we present in this section.

Observation 1: *Environmental quality and income are multimodally distributed.*

If the above observation is true (as will be demonstrated shortly), then an Environmental Poverty Trap may emerge implying that in a world of heterogenous institution and income pathways, the EKC may be non-unique over the distribution of environmental quality. The environmental trap that is likely to emerge in this case (as will be demonstrated shortly) would imply two things: (i) some countries may experience low institutional quality/income and low environmental performance and some would be perennially stuck at high institutional quality/income and high environmental performance, and (ii) when a multimodal (or bimodal) dependent variable (in this case, environmental quality) is used in empirical analysis, a regression approach beyond mean-based mechanism needs to be adopted. Moreover, the mechanism through which this 'trap' can occur is assumed in our paper, to be determined by dual presence of heterogenous income pathways and institutional quality. As a first step to show this, we need to define transitional dynamics of institutional structure, which we call as democratisation event chronology following Papaioannou and Siourousnis (2008). Second, we show that environmental quality is multimodally distributed.

Following Papaioannou and Siourousnis (2008), we identify countries with four democratisation episodes, viz., full democratisation, partial democratisation, borderline, and reverse democratisation. Following the authors, a country can be identified under full democratisation episode if the country experienced full democratisation for all years in our sample (1960-2003). Similar definitions apply for partial and borderline democratisation. Table 1 lists the number of countries under each of these episodes. Figures in the brackets indicate the year the event of specific democratisation episode occurred. As can be noticed from this table, there are 36 countries who are characterised by full democratisation episode, four by borderline, and eighteen by partial democratisation episodes. The rest of the countries have gone through mixed cycles of these episodes at various points of time and therefore are without specific patterns.

The persistence of the heterogenous institutional transition structure as described in Table 1 may also imply that there are multiple clusters of countries with similar institutional dynamics (this may also be called as 'multiple equilibria in democratisation events'). Additional support of such equilibria is also provided in Figure 1 where we have presented stochastic Kernel density plots of polity2 (or democracy) a la Quah (1997).[11] In contrast to simple Kernel density

[11] In an important research, Quah (1997) provides compelling argument that standard parametric regression methods fail to adequately capture heterogeneity in a number of important economic variables, such as world distribution of income. Given a significant correlation between income and institutional quality with pollution emission, it

Table 1: **Democratization Event Chronology**

Full Democracy	*Partial* Democracy	*Borderline* Democracy
Argentina (1983)	Albania (1992)	Iran Islamic Rep. (1997)
Benin (1991)	Armenia (1998)	Niger (1999)
Bulgaria (1991)	Bangladesh (1991)	Nepal (1991)
Bolivia (1982)	Ethiopia (1995)	Pakistan (1988)
Brazil (1995)	Georgia (1995)	
Chile (1990)	Guatemala (1996)	
Czech Republic (1993)	Indonesia (1999)	
Dominican Republic (1978)	Moldova (1994)	
Ecuador (1979)	Madagascar (1993)	
Spain (1978)	Mozambique (1994)	
Estonia (1992)	Malawi (1994)	
Ghana (1996)	Nigeria (1999)	
Greece (1975)	Nicaragua (1990)	
Guyana (1992)	Paraguay (1993)	
Honduras (1982)	Russian Federation (1993)	
Croatia (2000)	Turkey (1983)	
Hungary (1990)	Tanzania (1995)	
Korea, Rep. (1988)	Zambia (1991)	
Lithuania (1993)		
Latvia (1993)		
Mexico (1997)		
Mali (1992)		
Mongolia (1993)		
Panama (1994)		
Peru (1980)		
Philippines (1987)		
Poland (1990)		
Portugal (1976)		
Romania (1990)		
Senegal (2000)		
El Salvador (1994)		
Slovak Republic (1993)		
Slovenia (1992)		
Thailand (1992)		
Uruguay (1985)		
South Africa (1994)		

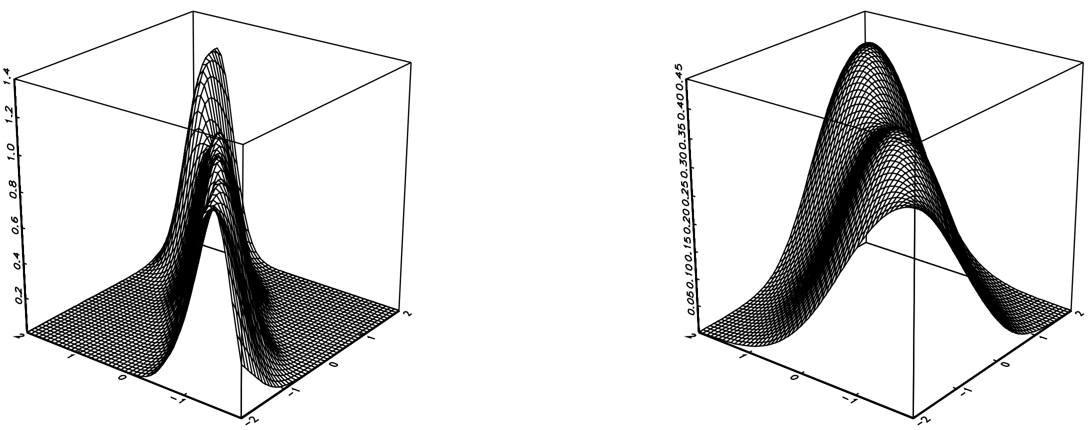
Note: Bracketed numbers represent the years when democratisation event occurred.

plots, the stochastic Kernel estimation reflects the transitional behavior of democracy, i.e., there are countries at high, medium and low levels (something very similar to what democratisation event chronology is attempting to identify). Using Markovian transition probability, transition behavior of economies have been estimated and countries with similar transitional dynamics have been clustered. As evident in Figure 1, there are three visible clusters for democratic distribution whereas for pollution (right panel) there are two clusters. The existence of clusters imply the existence of multiple equilibria within the same system. We have also performed this estimation for pollution per capita in case of 127 countries over the sample period 1960-2003. As presented in Figure 1 this also evince two visible clusters and that the null hypothesis of unimodality is rejected in both instances using Hartigan and Hartigan's (1988) Dip test at

is questionable therefore, whether the examination of this variable should be limited to the first-moment characteristics when in fact it is multimodality distributed.

5% significance level (results not presented here). It implies that both pollution and democracy comprise of clusters of economies with distinguished socio-economic-political attributes. In fact, the clustered economies share common stochastic trend and their strength of similarity is important in determining the evolutionary dynamics of the interdependent system.

Figure 1: Stochastic kernel density: Democracy [left] and Pollution [right]



Observation 2: *Under heterogeneous institutional and distribution structure, income-pollution relationship is non-unique.*

Having demonstrated using Table 1 and Figure 1 that there are heterogenous institutional structure within world economy, it might then make sense to assume that income-pollution relationship may also vary over changing patterns of institutional quality. That is, the relationship may be non-unique over democratisation episodes as identified in Table 1 and Figure 1. The heterogenous patterns are readily observed in Tables 2 and 3 where we present descriptive statistics and the correlation structure of income-pollution (as well as income-democracy, and democracy-pollution, for comparison) with respect to democratisation episodes and interquartile variations. The central messages these two tables offer are as follows: (i) Alongside increase in quartiles of income, CO_2, and polity2 (from 10th to 90th) it is clear that low quartile evince smaller growth of these variables whereas large changes are visible in higher quartile.

For instance, we can observe that between 10th and 90th quartile CO_2 is over 98 times bigger while income is over 20 times larger at 90th quartile than at 10th. As expected, polity2 is 1 at higher quartile as at this quartile countries are normally highly developed (this can be seen from high income level and high CO_2) and they may experience higher institutional quality (something which is often empirically observed).[12]. If we look at the evolving simple correlation structure between income and CO_2 interesting patterns emerge.

In Table 3 we have presented correlation coefficients of income-CO_2 ($r_{(CO_2,GDP)}$) along with CO_2-polity2 ($r_{(CO_2,Polity2)}$) and income-polity2 ($r_{(GDP,Polity2)}$). While for the full sample, the correlation coefficient between income-CO2 is 0.75, it is smaller for countries which have experienced full democratisation episode ($r_{(CO_2,Polity2)}$=0.57) and growing significantly and monotonically for countries with partial and borderline democratisation episodes. When the role of development heterogeneity is considered (for instance, low, middle, and high income classifications as per World Bank), income-CO_2 correlation appears to be the highest among middle-income and lowest among low-income countries. Similarly, correlation between CO_2 and polity2 is the highest for countries experiencing partial democratisation, while correlation between income and polity is the highest among countries with full democratisation episode. The latter correlation is expected and have robust empirical support, while the former (CO_2-polity2 relation) needs verification with rigorous modelling and estimation. On the whole, it appears that the unconditional correlation coefficients evince non-unique patterns across democratisation episodes and development pathways. These trends are also presented in Figures 2 and 3. Figure 2 presents how CO_2 per capita and polity2 have evolved over time under democratisation episodes (left upper panel: full sample; right upper-panel: full democratisation, lower panel left: partial democratisation, and lower panel right: borderline democratisation). In all figures, a common point emerges: a critical point occurs around the year 1990 where the growth of CO2 per capita and polity2 experience turns, possibly because of stricter environmental regulations that began in this decade). Similar patterns also can be observed between level of CO2 per capita and polity at various income pathways.

Table 2: **Descriptive statistics**

	Min	Max	10th	1st Quartile	Median	Mean	2nd Quartile	90th	Std Dev
Income	227.25	48217.25	909.31	1500.78	4385.75	7175.74	10739.74	18361.36	7163.56
CO_2	4.508	49305.14	103.93	377.78	1548.72	3884.25	6171.17	10286.7	5252.57
SO_2	0	30970	11	27	115	907.52	547.7	1972	2798.57
Polity2	0	1	0.1	0.15	0.4	0.495	0.9	1	0.375

5 Methodology and estimation

5.1 Methodology

One of the main conclusions of the stylized observations presented above is that the distribution of pollution concentration is multimodal. It is thus possible that both income and democ-

[12]The values have been rescaled: 0-10 is rescaled into 0-1 for convenience of comparison with other variables without affecting the generality of measurement issues

Figure 2: **Income and Pollution under Democratisation Event Chronology. Left upper panel: full sample; right upper-panel: full democratisation, lower panel left: partial democratisation, and lower panel right: borderline democratisation**

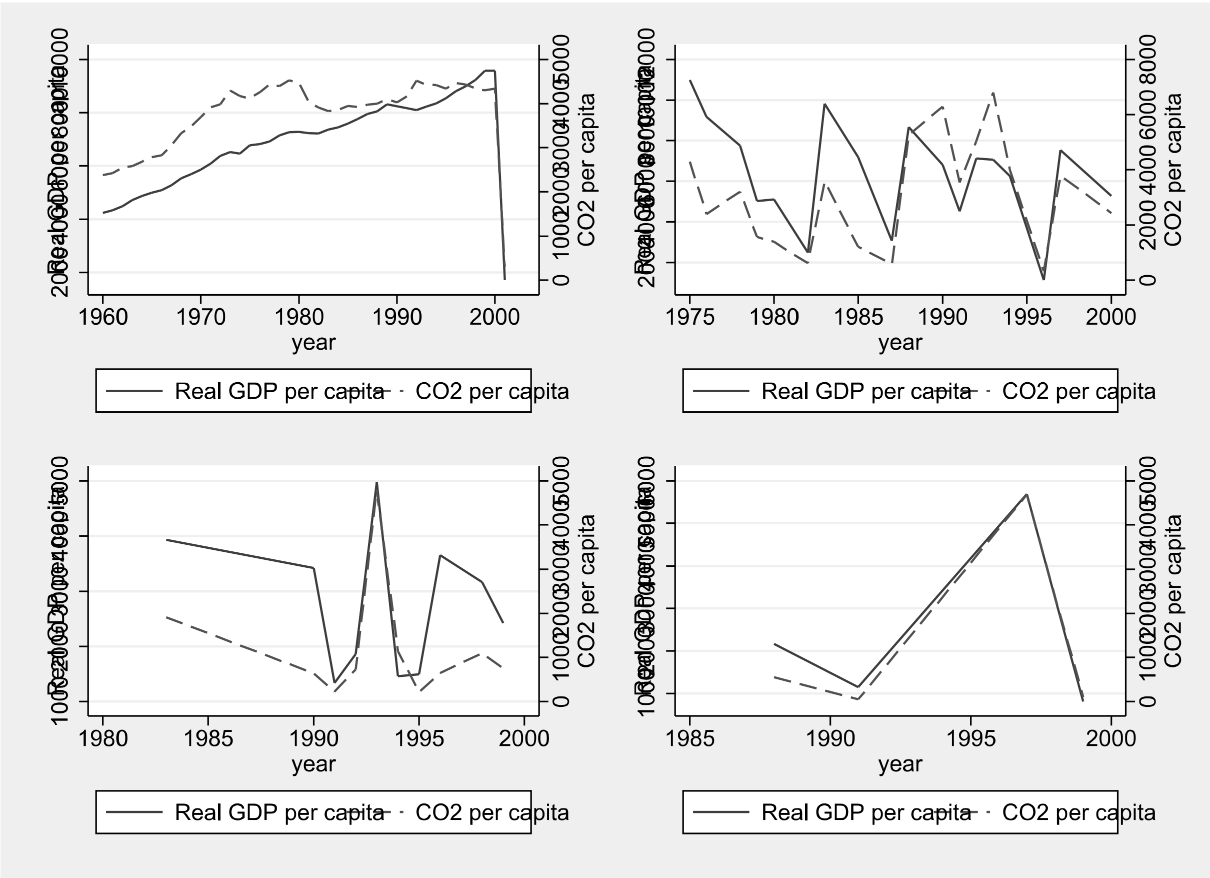


Figure 3: **Pollution per capita and Democracy under Heterogeneous Development. Left upper panel: full sample; right upper-panel: low-income lower panel left: middle income, and lower panel right: high income**

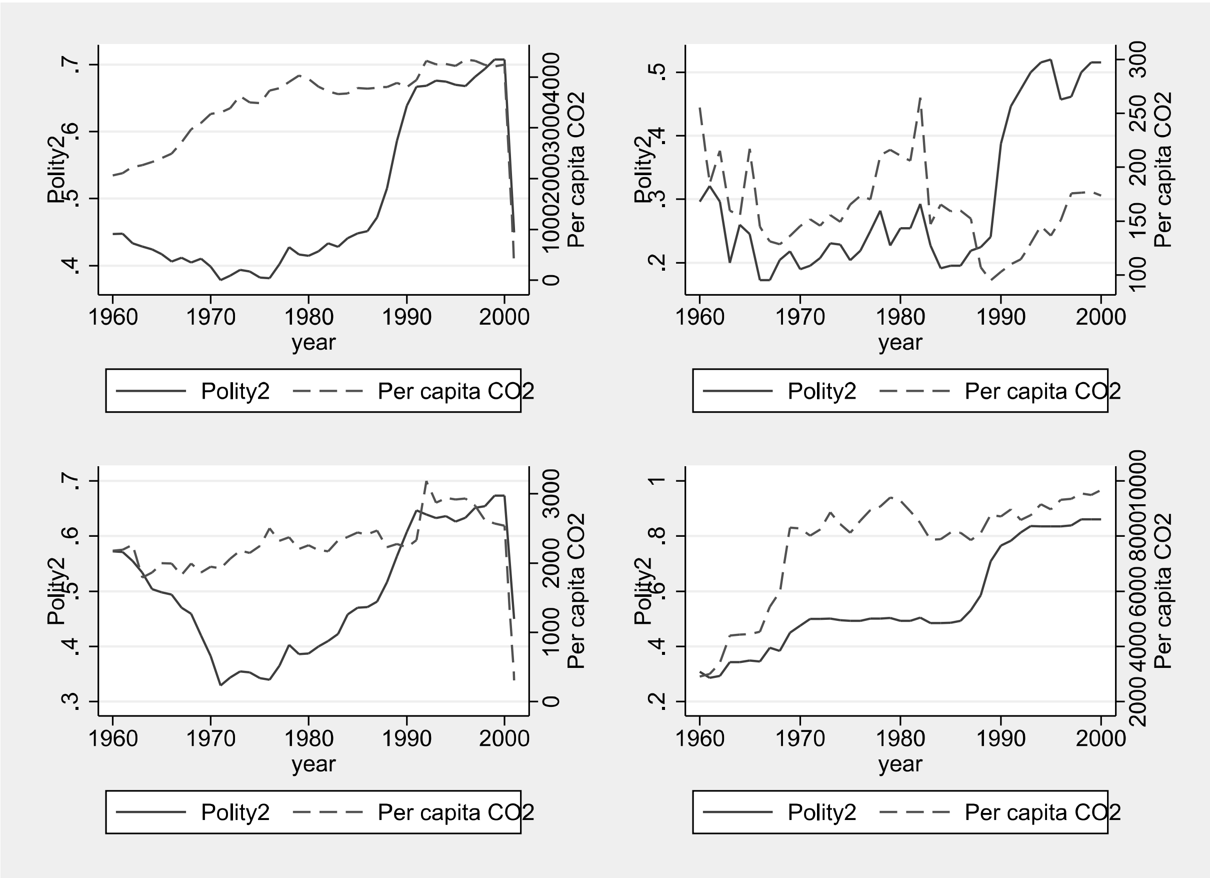


Table 3: **Correlation Structure**

Sample	$r_{(CO_2,GDP)}$	$r_{(CO_2,Polity2)}$	$r_{(GDP,Polity2)}$
Full Sample	0.75	0.43	0.53
(a) Full Democratisation	0.57	0.22	0.48
(b) Partial Democratisation	0.8	0.75	0.17
(c) Borderline Democratisation	0.98	0.46	-0.39
Low income	0.03	-0.06*	0.37
Middle income	0.67	0.27	0.4
High income	0.2	0.42	0.06
	$r_{(SO_2,GDP)}$	$r_{(SO_2,Polity2)}$	$r_{(GDP,Polity2)}$
Full Sample	0.31	0.24	0.53
(a) Full Democratisation	0.54	0.76	0.48
(b) Partial Democratisation	0.76	-0.097	0.17
(c) Borderline Democratisation	0.90	-0.58	-0.39
Low income	-0.081	-0.17	0.37
Middle income	0.32	0.05	0.4
High income	0.2	0.21	0.06

Note: All values are statistically significant at 5% level.

racy may exert non-homogenous effects on pollution at different quantiles of its distribution. For instance, it is expected that the effect on pollution of increasing democratic culture can vary according to income, geographic, and some demographic co-variates. Similarly, the effect of increasing income on pollution may vary along their development pathways and quality of institution. Therefore, estimating the causal effect of democracy or income on pollution using least squares estimation is uninformative because we tend to focus on estimating the conditional expectation of the dependent variable. The parameter estimated thereupon captures the marginal effect of democracy and/or income on pollution at the mean level.

Alternative approaches have been proposed in the literature. For instance, some recent research employ non-parametric method and compare the distribution of the dependent variable and the regressor. However, these methods inherit the natural limitation of focusing on the mean of the distribution and its changes in the shape of the distribution. What is required, however, is the effect of the regressor on the entire distribution of the dependent variable. Quantile regression approach has been proved very useful in this regard. In quantile regression, by specifying different covariate effects at different quantile levels we allow covariates to affect not only the center of the distribution (that is mean-based OLS estimation), but also its spread and the magnitude of extreme events. Indeed, by using quantile model we allow for unobserved heterogeneity and heterogeneous covariate effects. In addition, quantile regression allows for some conditional heteroskedasticity in the model (Koenker and Portnoy, 1996), and is a method that is more robust to outliers. The latter is often the case with EKC (see Flores et al., 2014 for some discussion).

We can write our income-pollution problem as follows:

$$P = y^{'}\gamma + \beta D + +\epsilon \tag{1}$$

$$D = f(y, z, \mu, \nu) \tag{2}$$

$$\epsilon = \mu + \lambda + u \tag{3}$$

where P denotes pollution per capita, x includes income and a vector of other exogenous variables, D is democracy. We assume that income (y) not only affects pollution (P) but also democracy (D). z is a vector of instruments which drive democracy but are uncorrelated with u and ν. The terms α, u, λ, and ν represent latent variables. While μ are country specific factors affecting the evolution of D and P, λ denotes time effects. As evident, we are interested in estimating γ, the causal effect of income on pollution, at different quantiles of the conditional distribution of pollution. The following possibilities arise:

- **The mean regression:** In a typical least squares approach, we focus on estimating:

$$E(P_{it}|y_{it}, D_{it}) = \gamma y_{it} + \beta D_{it} \tag{4}$$

In the case of conventional mean regression, γ captures the average or mean response of pollution due to a small change in income and other variables. What is missing in this estimate is the possibility of heterogeneous response of pollution to changes in income and other variables (most important in our case, democracy). For well-known theoretical reasons, it is now well-known that average response of the dependent variable is less informative of the actual dynamics that occurs between the regressors and the full range of distribution of the dependent variable. Indeed, this is the case in the present context. As demonstrated before, the unconditional distribution of pollution is strongly bimodal and even multimodal at different income groups (Figure 1). Thus, it seems that the analysis that focuses on the (conditional) mean of the distribution might miss important distributional effects of income and democracy. By looking at the tails of the distribution we may uncover richer evidence. The estimated conditional mean model of pollution crosses between the two clusters in our data, suggesting that pollution is associated with democratization in all countries. To capture this effect, quantile regression will offer a wholesome view of the effect of democratization on the entire distribution of pollution. Since we have observations both over time and across economies, a panel data setting for quantile regression would seem appropriate. The starting point, of course, would be to run a pooled quantile regression without distinguishing between country specific and time specific heterogenous effects. A pooled quantile regression is described as:

- **Quantile estimation: pooled regression**

$$Q_{P_{it}}(\tau|y_{it}, D_{it}) = \gamma(\tau) y_{it} + \beta(\tau) D_{it} \tag{5}$$

The parameter $\gamma(\tau)$ captures the effect of income at the τ-th quantile of the conditional distribution of pollution. This model can be estimated by solving the following minimization problem

$$\min_{\beta,\gamma} \sum_{i=1}^{N} \sum_{t=1}^{T} \rho_\tau(P_{it} - \gamma y_{it} - \beta D_{it}) \tag{6}$$

where $\rho_\tau(u)$ is the standard quantile regression check function (see, e.g., Koenker and Bassett (1978), Koenker (2005)). Since in the above equation, data are pooled over cross-section and time series, heterogeneities have been compromised. That is, we have ignored the potential issues of unobserved heterogeneity and endogenous covariates. This can be modified by allowing for fixed effects in the form of different individual country intercepts in the quantile regression.

- **Quantile estimation: panel regression**

Controlling for individual specific heterogeneity via fixed effects while exploring heterogeneous covariate effects within the quantile regression framework offers a more flexible approach to the analysis of panel data than that afforded by the classical Gaussian fixed and random effects estimators. Recent work by Lamarche (2008) and Geraci and Bottai (2007) have elaborated on this form of penalized quantile regression estimator. Abrevaya and Dahl (2008) have introduced an alternative approach to estimating quantile regression models for panel data employing the correlated random effects model of Chamberlain (1982).
To allow fixed effects in quantile panel regression, we re-write (5) as

$$Q_{P_{it}}(\tau|y_{it}, D_{it}) = \gamma(\tau)y_{it} + \beta D_{it}(\tau) + \mu_i \tag{7}$$

This model can be estimated for K quantiles simultaneously by solving,

$$\min_{\beta,\gamma,\alpha} \sum_{k=1}^{K}\sum_{i=1}^{N}\sum_{t=1}^{T} \omega_k \rho_{\tau_k}(P_{it} - \beta(\tau_k)y_{it} - \gamma(\tau_k)D_{it} - \mu_i) \tag{8}$$

The weight ω_k controls the influence of the k^{th} quantile on the estimation of the quantile effects. For our purpose, we have used equal weights (1/K).

In the presence of democracy as a possible explanatory variable for pollution per capita (in addition to income per capita), problem of endogeneity bias is a possibility as income and democracy variables are empirically observed to be correlated. To solve this problem, an instrumental variable approach needs to be adopted in quantile regression framework (see for instance, Chernozhukov and Hansen (2005) and Harding and Lamarche (2009) for detailed estimation procedures).

5.2 Empirical model specification and estimation issues

- **Empirical model**

Motivated by the appropriateness of quantile panel methodology for our objectives, we are now able to present the estimation equation and its functional forms. To comply with the extant literature on income-environmental quality, our estimation equation follows the tradition of the Environmental Kuznets Curve (EKC) construct. This paper's methodology is based around the joint estimation of two equations, one expressing pollution as a function of income, democracy and other factors and the second expressing income as a function of democracy and other factors.

$$P_{it} = \mu_i + \zeta_t + \alpha_1(\tau)y_{it} + \alpha_2(\tau)y_{it}^2 + \alpha_3(\tau)y_{it}^3 + \alpha_4(\tau)D_{i,t} + x_{it}^{'}\gamma(\tau) + \epsilon_{it} \tag{9}$$

$$y_{it} = \lambda_i + \theta_t + \beta_1(\tau)D_{i,t} + x_{it}^{'}\psi(\tau) + w_{it} \quad (10)$$

Eq. (10) expresses per capita income as a function of country and year specific effects (λ_i and θ_t), democracy (D) and X, a vector of other explanatory variables that have commonly been used within the growth literature (Mankiw et al., 1992; Levine and Zervos, 1993). These variables include measures of the capital stock per worker, human capital and population growth and are added incrementally to assess the sensitivity of the coefficient on democracy to the inclusion of additional explanatory variables.

where as before, P_{it} is pollution concentration for country i in year t, y_{it} is country $i's$ real GDP per capita in year t, D_{it} is state of democracy, x_{it} is a vector of controls including population density, age-dependency ratio, life-expectancy, etc. The cubic trend in income is consistent with previous studies (see e.g., List and Gallet, 1999), while the addition of political variables is less frequent, as argued in the preceding sections. We allow for the possibility that a country's political institutions may have a lagged effect on pollution, we run a model lagging the democracy variable. To control for any time invariant unobservables that vary by country, we run a fixed effects quantile panel regression, where μ_i in the equation above is a country-specific fixed effect. A fixed effects model is more appropriate than a random effects model because the unobservables captured by the fixed effect are likely to be correlated with the regressors. In the model above, a negative second derivative of pollution with respect to income for some range of income would be consistent with an inverted-U shape. If political institutions facilitate environmental improvement, we would expect a positive coefficient on the democratic index, where lower values of the index indicate a weak political institution.

$$\frac{\partial^2 P_{it}}{\partial y_{it}^2} = 2\alpha_2 + 6\alpha_3 y_{it} < 0 \quad (11)$$

- **Endogeneity issues**

Two types of endogeneity problems - largely ignored in EKC literature - can plague regressions of environmental quality on institutional and income variables. One type is the simultaneity bias introduced by the reverse causality of GDP and environmental degradation. While a rise in economic activity that comes along with increases in GDP may enhance in pollution growth. The latter as we know affects people's health, thereby reducing GDP via slackened productivity growth. Moreover, output and pollution may also be jointly produced in the production process, causing GDP and pollution to be simultaneously determined.

A second type of endogeneity problem arises from omitted variable bias. While inclusion of policy variables helps ameliorate the problem of endogeneity of GDP, it is still quite plausible that a third variable jointly causes both economic growth and environmental degradation-perhaps cultural or geographic factors not now in the regression formula. In order to mitigate the problems of endogeneity, we innovate upon the previous literature by employing an instrumental variables approach to make unbiased and meaningful inference of the effect of income on pollution. While an ideal source of exogenous variation of democracy is difficult to find, we use democracy in neighboring countries as an instrument for democracy. This approach introduces the concept of 'political distance' to define neighbors. The idea behind this instrument is that democracy in political allies has influence on domestic democracy but no direct impact on a countrys per capita income. Giuliano et al. (2013) uses this instrument to understand the effect of democracy on reform and argues that this can serve as a credible instrument. Other measures can be executive constraints such as bureaucratic quality, and political competition score as in (Bruckner et al., 2013). Detailed discussion of these alternate measures are presented in Section 6 (sensitivity analysis).

6 Results

In this section we present conventional panel estimation as well as quantile panel estimation results (using instrumental variables). Our sample comprises of 127 countries covering the period 1960-2010. Our estimation is performed in two stages. *First*, to minimize possible endogeneity bias between democracy and income in pollution per capita regression, we have performed the first stage regression of income per capita on democracy (eq. 10). Once we have performed the first stage regression of income-democracy relationship, we can then use the estimated democracy variable (which is now supposedly free from endogeneity bias) in our pollution regression in the *second* stage.

6.1 First stage estimation

As will be discussed shortly, to estimate the unbiased effects of income on pollution, it is necessary to remove possible endogeneity bias running between income and democracy. By instrumenting democracy with various measures which are correlated to democracy but uncorrelated to income, one would obtain a 'whitened' income which can then be employed to run regression of income on pollution with democracy as one of the important control variables. The channel through which democracy would affect pollution is assumed to be via the channel of income growth. Significant theoretical and empirical research exist on both strands: income and democracy (with reverse causation as well) and income with pollution per capita (EKC literature).

In case of the first one, it is not straightforward to estimate the impact of democracy on income. Among several challenges, Acemoglu et al. (2014) identified, for instance, that 'the existing democracy indices are typically subject to considerable measurement error, leading to spurious changes in the democracy score of a country even though its democratic institutions do not truly change.' Moreover, it is also argued that a reliable estimate of the impact of democracy on future GDP needs to account for the dynamics of the GDP process. Finally, even with year and country fixed effects, changes in democracy may be correlated with other changes or respond to current or future economic conditions, raising obvious omitted variable bias concerns (Acemoglu et al. 2005, Bruckner and Ciccone 2011). To avoid this, we have followed

Papaioannou and Siourounis (2008) and Acemoglu et al. (2014), and have built a dichotomous index of democracy that is free from spurious changes in democracy scores available in the standard datasets. In view of arguments for quantile approach in EKC regression, both the first and second stage estimations have been performed at various quantiles of the distribution of the dependent variable. Thus, instead of performing only mean-based estimation for the first stage estimation (as often is the case in conventional literature), for instance, we perform estimation at five quantiles and uncover the endogeneity-bias free estimated democracy variable. The latter would then be used in pollution-democracy estimation (eq. 9). Table 4 presents results from the first stage regression.

Table 4: **First stage estimation: Income and Democracy relationship. Dependent variable: per capita GDP at 2000 PPP.**

	Exogenous Democracy	R1	R2	R3	R3A Dynamic
	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5
GDP(-1)					0.834 (.0299)
Polity2	-0.010 (0.009)	-0.362 (0.055)	-0.303 (0.065)	-0.416 (0.095)	0.086 (.036)
K	0.233 (0.006)	0.345 (0.011)	0.323 (0.012)	0.332 (0.013)	0.114 (0.018)
H	0.117 (0.007)	0.094 (0.006)	0.102 (0.007)	0.090 (0.007)	0.041 (0.012)
Linfl	-0.0044 (0.0022)		-0.006 (0.0033)	-0.008 (0.0047)	-0.005 (0.002)
Trade	0.022 (0.008)			0.137 (0.020)	0.024 (0.012)
Density	-0.126 (0.035)			-0.558 (0.031)	-0.362 (0.072)
ngr	-0.005 (0.0021)			-0.010 (0.006)	-0.002 (0.009)
R^2	83	71	73	78	84
N. obs	1920	2298	1946	1920	1713
Sargan test		2.26 (p=0.44)	3.54 (p=0.37)	3.99 (p=0.28))	135.60 (p=0.87)

Results in Column 1 (Table 4) correspond to the assumption that democracy is exogenous and hence not instrumented. In all subsequent regressions (Col. 2 through Col. 5), democracy is instrumented (with institutional quality in the neighbouring country - as discussed earlier). Model (R1) begins by expressing pollution per capita as a function of capital per worker (K), human capital (H), and democracy ($Polity2$). The sensitivity and explanatory power of the model with democracy is checked by including additional explanatory variables (Models (R2) to (R3A)). The included variables are not based on random choice. Rather they have been regularly tested in previous studies (see for example Mankiw et al., 1992; Levine and Zervos, 1993; Cole, 2007; Mishra and Diebolt, 2010). These variables are the rate of inflation ($Linfl$), population growth (ngr), the openness of the economy ($Trade$), and population density ($Density$). Model R3A is dynamic (with the inclusion of a lagged dependent variable). The estimation has been performed by system GMM. The use of lagged GDP as an instrument captures mostly differences in GDP growth due to mean reversion.

In all models democracy ($Polity2$) is found to be a negative and statistically significant determinant of income except Model R3A, where the effect of democracy turns positive. Following the arguments of Acemoglu et al. (2014), we concur that estimation methods and construction of democratic index hold the key to finding whether democracy exerts positive or negative effect on growth. In Model R3A (Col. 5) when dynamic adjustment of GDP to its past value is introduced and consequently a system-GMM approach was employed, the coefficient of democracy turned from negative significant to positive significant (although smaller in magnitude). Moreover, as can be seen model R3A possess better explanatory power (R^2 = 0.84) is greater than the rest of the models. For subsequent empirical analysis therefore this model will be employed as our baseline regression.

Instrumenting democracy ($Polity2$) has the effect of increasing its coefficient in terms of both absolute value and statistical significance. The signs of the other explanatory variables are as expected, with the exception of population density ($Density$) which is expected to exert a growth-enhancing effect via technical change. The negative effect here suggests that high population density negative affect income (possibly through reduction in environmental quality and productivity slowdown). Finally, a Sargan test of overidentifying restrictions fails to reject the null hypothesis that the instruments are uncorrelated with the error term and that the specification is correct.

Given that a leading objective of this paper is to study income-pollution relationship under heterogeneity, our second stage estimation (i.e., the effect of endogeneity free income and democracy on pollution at each quantile) would require separate 'whitened' estimates of income at various quantiles. This would require a re-estimation of the chosen model from Table 4 at various quantiles of income distribution. Following our argument above, we choose Model R3A which accommodates empirically robust predictors of income and which includes elements of dynamic adjustment. Similar to Table 4, we observe negative effects of population density and population growth. Democracy ($Polity2$) displays consistently positive sign across various quantiles: Small positive and significant effects are observed at 10th and 90th quantiles, whereas relatively larger positive effects are noted for 25th and 50th quantiles. Other variables have evince expected effects and these are comparable to Table 4. Predicted values of income per capita at each quantile was obtained after netting out the effects of each variable in Table 5 from per capita income. Therefore, we have obtained five predicted values of income per capita each for τ = 0.10, 0.25, 0.50, 0.75, and 0.90. Our next task is to perform a second stage estimation of quantile panel regression of pollution on 'whitened income' and democracy.

Table 5: **First stage quantile estimation results for Model R3A. Dependent variable: per capita GDP at 2000 PPP**

	τ = **0.10**	τ = **0.25**	τ = **0.50**	τ = **0.75**	τ = **0.90**
GDP(-1)	0.772 (.0321)	0.681 (.0339)	0.690 (.0278)	0.713 (.0244)	0.801 (.0271)
Polity2	0.017 (0.009)	0.269 (0.067)	0.231 (0.101)	0.108 (0.021)	0.103 (.010)
K	0.241 (0.005)	0.342 (0.021)	0.333 (0.018)	0.309 (0.020)	0.208 (0.012)
H	0.114 (0.003)	0.173 (0.005)	0.121 (0.004)	0.087 (0.006)	0.059 (0.016)
Linfl	-0.014 (0.002)	-0.018 (0.004)	-0.0023 (0.002)	-0.033 (0.003)	-0.046 (0.001)
Trade	0.029 (0.006)	0.020 (0.014)	0.022 (0.011)	0.112 (0.026)	0.179 (0.016)
Density	-0.101 (0.090)	-0.098 (0.064)	-0.201 (0.012)	-0.359 (0.110)	-0.410 (0.119)
ngr	-0.005 (0.0021)	-0.009 (0.002)	-0.105 (0.031)	-0.010 (0.006)	-0.002 (0.009)
R^2	60	65	70	69	66
N. obs	1516	1499	1610	1644	1671

6.2 Second stage estimation

Table 6 presents results of panel quantile fixed effects[13] regression of pollution per capita on predicted income and democracy ($Polity2$). Table 6 also presents results for Sufur dioxide (SO_2, as a dependent variable), however, we will discuss in details the results corresponding to this dependent variable in the section on Robustness. For our purpose, we will provide a comparative note.

Interesting results emerge on the existence of EKC and its consistency across quantiles. In all quantiles, we find negative (but variable) effects of democracy ($Polity2$) on both CO_2 and SO_2. The results comply with theoretical expectations (as reviewed in the literature, Section 2) that greater political participation (or higher Polity2) would decrease emissions (both CO_2 and SO_2). In particular, small negative effects are observed at the lowest (10th) and 25th quantiles and larger negative effects are observed for 50th (median), 75th and 90th quantiles. Irrespective of variable magnitudes of democracy, the unique feature of our result is that a consistent negative effect of democracy is observed irrespective of whether one is talking about lower or higher-end of pollution distribution. As far as theoretical expectation goes, for low polluting economies (i.e., at lower quantiles), the response of emission growth to improvement in institutional quality would be slower than those of highly-polluting economies where further imposition of stringency in environmental regulation via greater political participation would reduce emission growth to a great extent. Low-polluting economies normally possess strong political institutions and therefore, these economies may not respond in the same way as would highly polluting economies. This is indeed explained by the coefficients of $polity2$ on pollution per capita (CO_2) at various quantiles. Results are overall consistent with when local emission,SO_2, is used as our dependent variable.

Our next task is to investigate if (inverse) EKC exists at various quantiles of pollution distribution. In general, we find that - for all quantiles - both pollutants possess a statistically significant cubic relationship with per capita income. What is interesting in our case is the existence of EKC at smaller quantiles and disappearance at higher quantiles. In particular, we observe that at 10th, 25th, and 50th quantiles (except for CO_2), the coefficients corresponding to square of GDP display significant negative effects - providing evidence of the existence of EKC in those quantiles. At higher quantiles of pollution distribution (i.e., at for instance, 75th and 90th quantiles), EKC disappears (the coefficients of squared GDP presents positive significant effects). The existence and disappearance of EKC - or what we argue - the non-uniqueness of EKC across quantiles is important for further economic theoretic research as well as policy debates.

The results although unique is not completely random as Flores et al. (2014) investigating the effects for USA also provide evidence of heterogeneous effects of EKC at various quantiles. Because we have a cross-country setting, the existence of EKC at lower quantiles may imply the following. Countries with lower levels of pollution (low quantiles) are primarily with low per capita income. Therefore, those economies might display an inverted U-shape in pollution (EKC): when they move steadily in income ladder, after certain critical level of income (with

[13]We also performed quantile panel random effects estimation. Using Hausman specification test (the values were respectively, 20.4 (for $\tau = 0.10$), 23.9 (for $\tau = 0.0.25$), 23.6 (for $\tau = 0.50$), 18.9 (for $\tau = 0.75$), and 19.0 (for $\tau = 0.90$)), we accepted (at 5% significance level) the null hypothesis of consistency of fixed effects.

higher pollution), these economies would tend to care more for environment and hence may revert to green technologies or alternative mechanisms to reduce pollution growth. The disappearance of EKC at higher pollution levels is also consistent with economic theory: economies with higher pollution growth are either large economies (like India and China) which are trying to capitalise on high growth momentum by producing (and hence emitting) more. These may also be the developed nations who have already achieved higher emission growth. In this case, the disappearance of EKC does not imply that these economies care less for environment and health. Rather, the disappearance may well be linked to relative pollution growth (in comparison to the countries at lower-quantile of pollution distribution). Finally, both industry share ($Ind.share$) and Trade are found to have positive and significant effects on pollutants, which meets theoretical expectations.

Table 6: **IV Quantile Panel Regression Results SO_2 and CO_2**. Bracketed values are standard errors. ***, **, and * indicate significance at 1, 5, and 10 percent levels.

τ		τ=0.10		τ=0.25		τ=0.50		τ=0.75		τ=0.90
	SO_2	CO_2	SO_2	CO_2	SO_2	CO_2	SO_2	CO_2	SO_2	CO_2
Polity2	-0.511***	-0.216***	-0.907	-0.291***	-0.815***	-0.416***	-0.788***	-0.634***	-0.884	-0.683***
	(0.141)	(0.021)	(0.114)	(0.016)	(0.175)	(0.014)	(0.345)	(0.016)	(0.764)	(0.021)
GDP	0.068**	0.045	0.047**	0.101**	0.229***	-0.509***	-0.211***	-0.197***	-0.439	-0.493***
	(0.034)	(0.062)	(0.028)	(0.047)	(0.013)	(.0411)	(0.025)	(0.046)	(5.383)	(0.063)
GDP^2	-0.601***	-0.320***	-0.292	-0.112***	-0.109	0.182***	0.218***	0.1959***	0.511***	0.574***
	(0.155)	(0.082)	(0.133)	(0.062)	(0.176)	(0.054)	(0.034)	(0.061)	(0.073)	(0.082)
GDP^3	0.085***	0.005**	0.009*	0.020	0.040***	-0.027**	-0.053***	-0.044**	-0.176***	-0.203***
	(0.007)	(0.002)	(0.0044)	(0.022)	(0.008)	(0.010)	(0.015)	(0.027)	(0.032)	(0.036)
Ind. Share	0.413***	0.357	0.506***	0.502***	0.673***	0.826***	1.032***	1.533***	1.870***	2.402***
	(0.041)	(0.233)	(0.032)	(0.175)	(0.049)	(0.154)	(0.113)	(0.174)	(0.330)	(0.236)
Trade	0.151***	0.221***	0.168***	0.212***	0.196***	0.196***	0.219***	0.253***	0.562***	0.766***
	(0.014)	(0.085)	(0.011)	(0.064)	(0.018)	(0.056)	(0.037)	(0.063)	(0.097)	(0.086)
constant	-5.961**	9.159	10.892***	23.331**	6.782**	13.241*	53.879***	49.631***	103.299***	113.522***
	(2.817)	(15.169)	(2.483)	(11.116)	(3.260)	(10.051)	(6.104)	(11.343)	(12.872)	(15.337)
N	2786	2786	2786	2786	2786	2786	2786	2786	2786	2786

7 Robustness analysis

In this section, we perform sensitivity check of our results by first, introducing alternate measure of institutional quality, and second, by estimating model with a different indicator of environmental quality. For the latter, we use Sulphur dioxide (SO_2) data from NASA Socioeconomic Data and Applications Center (SEDAC) (Smith, et al., 2011). As described by Cole (2007), large proportions of SO_2 and CO_2 stem from industry and energy generation. When compared with respect to their atmospheric lives[14], Cole (2007) argues that SO_2 will perhaps reach 1000 km

[14]That is, the time taken for approximately two-thirds of an emission to be lost from the atmosphere and it is these lifetimes that determine the range of effect of each pollutant.

before decaying and hence has only a local and regional impact.[15] In contrast, the long atmospheric lifetime of CO_2, a greenhouse gas, means that a global impact is possible, whilst no known local impact exists. Therefore, using SO_2 in addition to CO_2 as our main dependent variable in EKC regression provides a robustness check of our main hypothesis that there is a non-unique effect of income and institution on various parts of environmental quality.

With regard to the second strategy of robustness exercise, we use a substitute measure of democracy, viz., democratization index of Papaioannou and Siourounisuse (2008), and data on bureaucratic quality. Details of construction method of democratisation index and its usefulness for empirical research has been summarized in the section on Data. However, we recall the main idea and construct of this indicator. The democratisation indicator that takes the value of 1 in year t if the country is a democracy in year t but was an autocracy in year $t-1$; and an autocratic reversal indicator that takes the value of 1 in year t if the country is an autocracy in year t but was a democracy in year $t-1$. Indeed, there are ample evidence in the literature which suggests that democratization improves environmental performance by way of progressively doing away with various bureaucratic controls and allowing greater degree of autonomy to citizens. With respect to bureaucratic quality, the score lies between 0-6: where high scores indicate 'autonomy from political pressure' and 'strength and expertise to govern without drastic changes in policy or interruptions in government services'. Compatible with a number of research in the literature, where it is argued that strict bureaucratic controls often restrict adoption of stringent environmental policies, using this measure will help us understand the robustness of the effect of democracy on pollution.

The fist column of Table 6 at each quantile presents results of EKC regression when an alternative measure of emission is used. Table 7 presents results with alternative instrument specifications for democracy: Robust 1, with democratization index, and Robust 2, with bureaucratic quality. As evident from Table 6, SO_2 evince similar patterns as CO_2 but with stronger negative effects for democracy. EKC is satisfied at lower quantiles - a result similar to CO_2. How sensitive are our results when we use alternative measures of democracy as instruments. The dependent variable is CO_2 per capita. The results are presented in Table 7. The first part of the results are concerned with estimation where democratisation index is as a measure of democracy. The lower panel results of Table 7 concern the use of bureaucratic quality as a measure of political competition. In general we observe that in the presence of alternative measures of democracy, our results of EKC are consistent with the results presented in Table 6. This is expected as both democratization index and bureaucratic qualities directly reflect the extent of control on the overall economic system and therefore one would expect at least similar (but could be stronger) effects of the existence of EKC over quantiles.

8 Discussion and conclusions

In a panel quantile setting and employing an instrumental variable (IV) approach we argued that the frequently observed inverted *U*-shaped relationship between income and environmental quality - the Environmental Kuznets Curve (EKC) - is significantly non-unique over the

[15] The health impacts of SO_2 include respiratory problems, reduced resistance to infection. It is also believed to be partially responsible for the acidification of lakes, rivers and forests.

Table 7: **Robustness Check: IV Quantile Panel Regression**. Bracketed values are standard errors. ***, **, and * indicate significance at 1, 5, and 10 percent levels.

			Robust 1: Democratization		
			Democratization		
τ	**10**	**25**	**50**	**75**	**90**
Democratization	-0.375***	-0.361***	-0.326**	-0.494***	-0.274***
	(0.021)	(0.090)	(0.111)	(0.122)	(0.057)
GDP	0.86***	0.550***	0.699***	-0.243***	-0.819***
	(0.279)	(0.092)	(0.085)	(0.030)	(0.022)
GDP^2	-0.185***	-0.219***	-0.232***	0.212***	0.201***
	(0.012)	(0.016)	(0.033)	(0.058)	(0.112)
GDP^3	0.008**	0.011***	0.013	-0.014***	-0.015***
	(0.004)	(0.002)	(0.004)	(0.003)	(0.005)
Ind. Share	0.529***	0.341***	0.184***	0.347*	0.893**
	(0.091)	(0.040)	(0.029)	(0.096)	(0.401)
Trade	0.308***	0.296***	0.212***	0.146**	0.108
	(0.084)	(0.016)	(0.087)	(0.073)	(0.081)
			Robust 2: Bureaucratic quality		
			Bureaucratic quality		
τ	**10**	**25**	**50**	**75**	**90**
bquality	-0.164***	-0.114***	-0.294***	-0.308***	-0.501***
	(0.021)	(0.023)	(0.021)	(0.017)	(0.018)
GDP	0.078*	0.093**	-0.103	-0.182**	-0.123**
	(0.042)	(0.039)	(0.094)	(0.097)	(0.011)
GDP^2	- 0.065***	- 0.069***	0.082***	0.089***	0.087***
	(0.007)	(0.005)	(0.006)	(0.009)	(0.011)
GDP^3	0.007***	0.008***	-0.012***	-0.010***	-0.011***
	(0.001)	0.001	(0.001)	(0.002)	(0.001)
Ind. Share	0.258***	0.347***	0.431***	0.501***	0.407***
	(0.102)	(0.091)	(0.086)	(0.093)	(0.079)
Trade	0.274***	0.274***	0.335***	0.333***	0.348
	(0.139)	(0.146)	(0.123)	(0.114)	(0.212)

distribution of emission path when (i) an estimation environment beyond median regression is considered, (ii) (heterogeneous) effects of institutional quality on pollution is modelled, and (ii) possible endogeneity bias between institutional quality and pollution is identified and treated. These are important for drawing valid inference on income-environmental quality relationship. However, extant empirical research weakly documented a definitive role of institutional quality for the existence and variability of EKC. Similarly, there was insufficient exploration of the simultaneous role of distributional heterogeneity and endogeneity bias in establishing a unique EKC relationship. We attempted to fill in these gaps in the literature. Our IV quantile panel estimation demonstrates that (i) institutional quality is an important determinant of EKC, and that (ii) EKC is non-unique over the distribution of environmental quality. Significant variability for the effect of institution on pollution is observed: EKC is confirmed at lower quantiles while it is observed to disappear at higher quantiles. Our results are robust across choice of instrumentation and/or alternative measurement of emission.

Among other notable contributions, we also showed that cross-country distribution of environmental pollution shows significant multimodal pattern. This indicates the possible existence of multiple equilibria in the environmental quality: that is, economies are clustered around low, medium, and high level of pollution-democracy equilibria calling for strategic policy actions to break the cycle of environmental trap. Secondly, because environmental quality is multimodal, the conventional mean-based estimation approach even with instrumental variable regression to account for endogeneity or other estimation issues, is weak in terms of policy significance. Informed and efficient policy decisions are always contingent upon models which are rich in heterogeneity in the response variable and appropriately accounts for endogeneity and persistence issues in the estimation. The panel instrumental quantile regression approach in this case, ameliorates some of the existing estimation problems in the environment-democracy-economic development model. An important implication of our results is that existence or non-existence of EKC depends on the modelling strategy and choice of instruments and additional regressors. In this context, we underlined the centrality of institutional quality in shaping income-environment relationship.

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