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# Are Autocracies Bad for the Environment? Global Evidence from Two Centuries of Data

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## Abstract

This study examines the effects of the rule of law on carbon-dioxide emissions using a large sample of countries for over a century. In principle, the turning point of the Environmental Kuznets Curve (EKC) is compared for a range of countries lying between autocracy and democracy. Using decadal data for 220 years (1790-2010) and 150 countries, we use country fixed effects estimation technique to quantify the absolute and interactive effects of autocracy-democracy index on carbon-dioxide emissions. Results show that democracies emit less carbon-dioxide for one unit increase in per-capita income, leading to lower turning point and thus lower emission. The turning point in case of autocracies are more than twice of the turning point for democracies. Electoral autocracies have lower turning point in comparison to closed autocracies. Point estimates are robust to alternative estimation techniques and are not likely to be influenced by omitted variable biases. Strengthening rule enforcement and improving access to justice can be critical in decreasing carbon-dioxide emissions.

**Keywords**

EKC, Turning Point, Rule of law, Democracy, Autocracy

**JEL Classification**

Q50, Q53, Q58

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**Abstract**

This study examines the effects of the rule of law on carbon-dioxide emissions using a large sample of countries for over a century. In principal, the turning point of the Environmental Kuznets Curve (EKC) is compared for a range of countries lying between autocracy and democracy. Using decadal data for 220 years (1790-2010) and 150 countries, we use country fixed effects estimation technique to quantify the absolute and interactive effects of autocracy-democracy index on carbon-dioxide emissions. Results show that democracies emit less carbon-dioxide for one unit increase in per-capita income, leading to lower turning point and thus lower emission. The turning point in case of autocracies are more than twice of the turning point for democracies. Electoral autocracies have lower turning point in comparison to closed autocracies. Point estimates are robust to alternative estimation techniques, and are not likely to be influenced by omitted variable biases. Strengthening rule enforcement and improving access to justice can be critical in decreasing carbon-dioxide emissions.

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# 1 Introduction

Increasing concentration of carbon-dioxide (one of the major anthropogenic greenhouse gas (GHG)) has been argued to be one of the major causes of rising global temperature. The fifth assessment report of the Intergovernmental Panel on Climate Change suggests that if the carbon emission continues at present rate then global mean temperature will increase by $4{\cdot}C$ or more above pre-industrial levels by the end of 21st century (Collins et al., 2013). It is widely agreed that the global mean temperature should not be allowed to increase by more than $2{\cdot}C$ above pre-industrial levels to minimize the risk being posed by climate change (Edenhofer et al., 2014).[1] Achieving $2{\cdot}C$ target implies serious reduction in carbon-dioxide emissions. So far, the focus of the literature on maintaining the $2{\cdot}C$ target has been centered around renewable sources of energy and improvements in energy efficiency (Grubb, 2014, p. 14). However, little is understood of how politic–economic institutions affects the decisions to keep environmental standards.

The relation between political/economic activity and carbon-dioxide emissions could be formulated in terms of the environmental Kuznets curve (EKC). EKC being a reduced form relationship between per-capita emission and per-capita income suggests that per-capita carbon-dioxide emission initially increase with per-capita income, and then declines after the threshold level of per-capita income, also known as the 'turning point'. Grossman and Krueger (1995) argue that changes in income affect living standards, environmental regulations, technology and industrial compositions, and thus environmental pollution. It is well known fact that as per-capita income increases, initially the share of manufacturing in gross domestic product increases, and then after certain level of per-capita income, share of manufacturing starts declining.

A large body of literature has found the existence of an EKC-type relationship between various measures of environmental quality and per-capita income.[2] However, less is

[1] This $2{\cdot}C$ target has been recently endorsed by 195 nations under United Nations Framework Convention on Climate Change (UNFCC) in Paris.

[2] See Grossman and Krueger (1991); Shafik and Bandyopadhyay (1992); Shafik (1994); Selden (1994); Grossman and Krueger (1995); Panayotou (1995)). Jebli et al. (2016), Apergis and Ozturk

understood of how the relationship between economic activity and environmental quality is influenced by political institutions that govern the process of policy making in a particular country. Studies have found that the connection between environmental protection and civil and political rights is a close one. "As a general rule, political and civil liberties are instrumental in protecting the environmental resource-base, at least when compared with the absence of such liberties in countries run by authoritarian regimes" (Dasgupta and Maler, 1995, p. 2412). Payne (1995) argued that in democracy, people are better informed about environmental problems due to press freedom and can express their environmental concern (freedom of speech). People can organize for better environment (freedom of association) and that puts pressure on political establishment for improving environmental condition. In non-democratic system, the ruling class is under no such pressure to improve environmental standards.

Using data for more than 200 years (1790-2010) and 150 countries, first we examine if the EKC holds in the baseline country fixed effects model for the whole sample, 150 countries, and the entire time period, 1790-2010, and if it continues to hold in extended models estimated for the time period 1950-2000 and 1960-2000. Time period and number of countries included in these estimates are based on available data, and are explained in next section. Our results suggest that political institutions are important for determining turning point of EKC for the time period 1950-2000 and 1960-2000. Political institutions are expected to work through marginal emission intensity (change in emission for an unit change in per-capita income). We anticipate that democratic institutions would have more environment friendly methods of economic activity as there would be demand for better environmental conditions. We provide the evidence of significant differences in marginal emission intensity due to differences in prevailing institution from both simple as well as threshold regression model with country fixed effects. The marginal emission intensity is significantly lower in democracies in comparison to autocracies.

(2015), Ozturk and Al-Mulali (2015), Kang et al. (2016) and Lv (2017) are few recent studies in case of atmospheric pollution. Dinda (2004) Müller-Fürstenberger & Wagner (2007) and Kaika & Zervas (2013a, 2013b) provide excellent survey on EKC hypothesis.

Regimes of the world data that we use for analysis categorized countries in four groups; (i) closed autocracy (ii) electoral autocracy, (iii) electoral democracy, (iv) liberal democracy. We find that a one unit change in per-capita income in democracies significantly lowers carbon-dioxide emissions in comparison to autocracies. Thus giving a significantly lower turning point in case of democracies. Threshold income (turning point) in autocracies are more than twice of that in democracy and this is true for several measures of autocracy and democracy used in our analysis. In EKC literature the impact of institution on turning point estimates have been criticized due to the possibility of omitted variable bias (Stern 2004; Kaika & Zervas, 2013a,b). We correct for this bias using Oster (2019) test for omitted variable bias. This test is based on relative importance of possible excluded and included variables. The test implies that omitted variables must be more that 5 times more relevant in comparison to the included variables for the coefficient of interest i.e., institutions to be insignificant. Test results show that it is unlikely that the significance and the sign of the institution coefficient is biased due to omitted variable. Therefore, this paper contributes to the literature by providing robust effect of institutions on emission.

We also show that the widely used institution variable, 'polity' is not able to capture the impact of elections on turning point. Using regimes of the world data we show that election matters for emission in autocracies. Turning point for electoral autocracies are less than closed autocracies. At the same time there is no differential impact of elections on turning point in autocracy and democracy. Liberal democracies have additional positive differences with electoral democracy such as transparent rule enforcement and access to justice. This further lowers turning point in liberal democracy in comparison to electoral democracy. We estimate both simple and threshold regression with country fixed effects. We argue that institutions are expected to work through marginal emission intensity and therefore interaction effects are important. Ignoring this interaction effect can lead to biased estimates.

# 2 Literature Review

Olson (1993) and Deacon (2003, 2009) argued that democracy is better environmentally because non-democratic regimes tend to under produce environment. Their argument stems from the politico-economic structure of autocracies wherein a large chunk of productive resources are owned by few elites, who would care less for public goods as compared to private benefits. Therefore, the imposition of better environmental standards can lower private consumption in autocracies, which autocrats would tend to avoid. Since the marginal benefit of better environment (public good) is same for all groups, it is likely that autocratic elites would not be in favor of better environmental standards.

The above argument does not analogously apply to democracies, as is not clear ex ante that democratic institutions will have lower emissions, this is due to two opposing forces. On one hand, democracies with private property rights and individual liberty are suitable for businesses in comparison to non democratic set-ups, therefore, these systems might exert higher pressure on the environment owing to the higher level of economic activity. On the other hand, democracies may tend to lean towards citizen preferences, and thus, in a relatively richer country, the demand for lower emission and strong environmental regulations could be adhered to. These insights makes the role played by political institutions in influencing the relation between per-capita emission and per-capita income critical.

Congleton (1992) analyzed the effect of political regimes (democratic or autocratic) on environmental regulation and suggested that political and institutional arrangements, rather than resource endowments largely determine policies concerning environmental regulation. Neumayer (2002) argued that in democracies greater percentage of their land area is under protected status. Accordingly, Fiorino (2018) argued that democracies delivers higher level of environmental performance through greater innovations in technology and better climate governance. Castiglione et al. (2012) suggest that stronger rule of law decreases the turning point of the EKC, thus, decreasing emissions. Cole (2007) provide evidence that increase in corruption leads to increase in pollution. Ivanova (2010) argues

that better rule of law and lower level of corruption reduces sulphur emissions. Fredriksson and Wollscheid (2007) suggest that parliamentary democracies achieve greater reductions in greenhouse gases, whereas presidential democracies are similar to autocracies in terms of pollutant emissions. Bernauer and Koubi (2009) suggest that democracies provide cleaner environment on average and presidential democracies performs better than parliamentary democracies. Bernauer and Koubi (2009) also provide evidence in support of civil liberties protecting the environment. Neumayer (2003), Binder and Neumayer (2005), Li and Reuveny (2006) and Villanueva (2012) too provide evidence in favor of lower environmental damage associated with more democratic institutions.

Scruggs and Rivera (2008) argue that there is no evidence that democratic countries have lower level of pollution. According to them increasing strength of traditional left-wing parties leads to lower pollution levels. Carlsson and Lundstrom (2003) argue that political freedom has no effect on reducing levels of CO2 emission. Gill (2019) suggest that democracies delayed the turning point in ASEAN countries, which supports the argument that democracy leads to less pollution. Lv (2017) using data from 19 emerging economies suggested that a change towards democratic institutions after reaching a certain threshold level of income reduces emission. This suggests that the relationship between emission and institution depends upon the level of income. Laegreid et al. (2018) suggest that countries with democratic system, less corrupt government and active civil society participation emit less carbon-dioxide for an unit increase in per-capita income. They also argue that active civil society participation in rich countries is instrumental in mitigating the adverse effect of per-capita income on emission. Povitkina (2018) using panel of 144 countries over time period 1977–2011 argued that in the absence of corruption, democratic systems led to lower emissions. The above discussion shows that there is no consensus about the role of political institutions in affecting carbon-dioxide emissions.

# 3 Data

Our historical data covers the time span for data is 1790-2010 and is derived from multiple sources. Apart from per-capita emission and per-capita income variables which are our main variables of interest, all the other variables used in this study are available for lesser time periods. The decadal frequency of the data is ideal as it allows us to examine the relationship between environmental degradation and institution in the long run. The decadal data also allows us to get rid of the fluctuations caused by business cycles in income and emission, and captures the gradual changes in institutions.

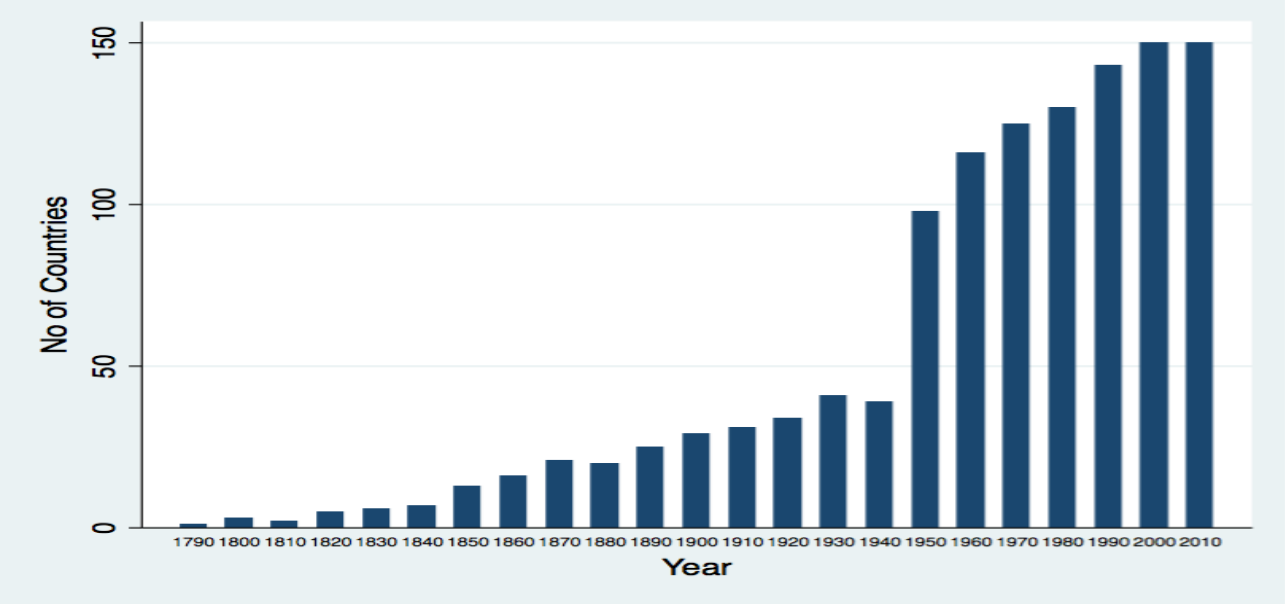


Figure 1: Year Wise Number of Countries with data of per-capita income and per-capita carbon-dioxide emission between 1790-2010

Figure 1 gives the number of countries for each decade being used in our analysis. We start with per-capita carbon-dioxide emission, per-capita income, population density, trade to gross domestic product ratio, and a measure of political institution. per-capita carbon-dioxide emission is derived from c*lio infra*[3] for the time period between 1790-

[3]Clio Infra provides a number of interconnected databases containing worldwide data on social,

2010. The original source for carbon-dioxide emissions are from the estimates of the carbon-dioxide Information and Analysis Center (CDIAC). per-capita income is derived from V-Dem (version 9) and is between 1790-2010. The original source for per-capita income is Maddison Project Database (2018).

Our primary institution variable is *polity 2* ranging between -10 (total autocracy) and 10 (total democracy) and comes from Polity IV dataset (Marshall et al., 2016). This index is for time period 1800 to 2010. Polity 2 has been widely used in exploring the impact of institutions on emissions as well as economic growth. In Polity IV dataset the variable, *institutionalized autocracy score* is measured on a scale, 0-10. *Institutionalized democracy* is on a scale 0-10 and has three essential elements: (i) individual can express their preferences about policies and leaders, with existing institutional framework, (ii) sufficient institutionalized constraints exists on exercise of power by the head of the government, (iii) civil liberties for all citizens for their daily life as well as for political participation. The "polity score" is computed by subtracting the autocracy score from the democracy score and lies between +10 (strongly democratic) to -10 (strongly autocratic). Polity 2 is obtained by converting "standardized authority scores;"-66, -77 and -88"[4] such that final score lies between -10 and 10.[5]

economic, and institutional indicators for the past five centuries. see https://clio-infra.eu/ for details.

[4] -66: cases of foreign interruption, -77: anarchy, -88: cases of transition

[5] see V-Dem version 9 for more details.

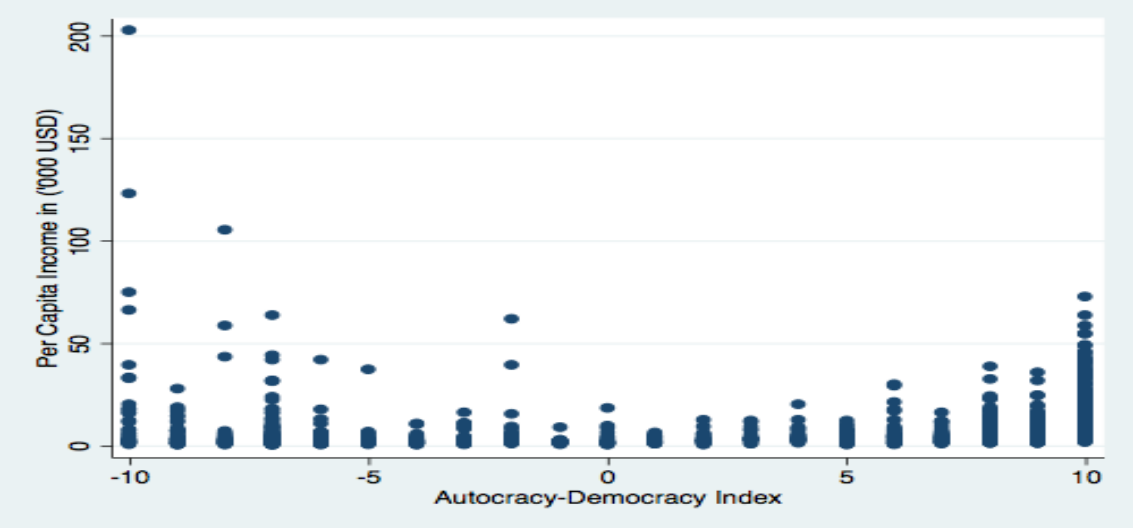


Figure 2: per-capita Income and Autocracy-Democracy Index: Time Period; 1800-2010.

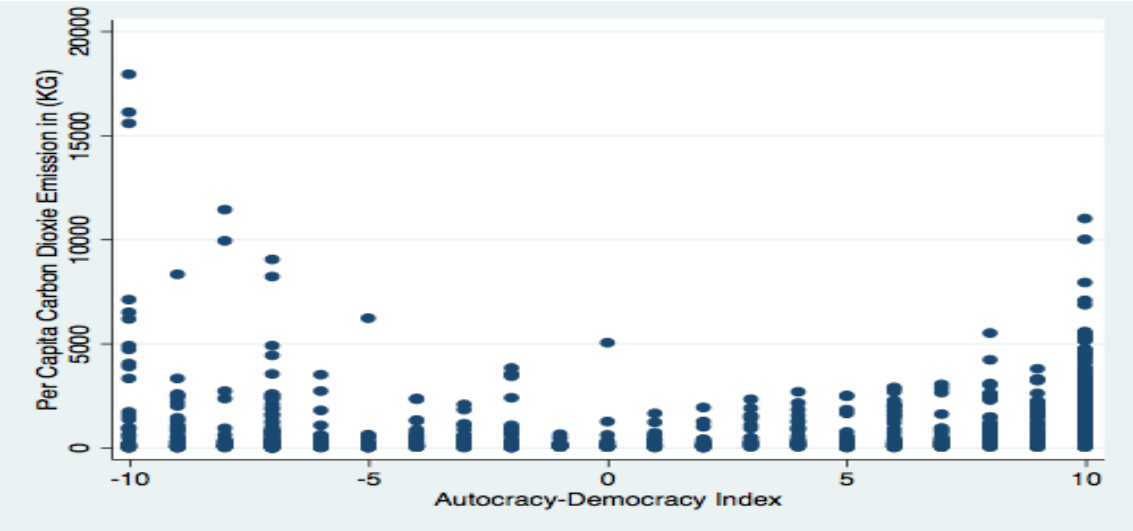


Figure 3: per-capita CO2 Emission and Autocracy-Democracy Index: Time Period; 1800-2010.

*Polity 2* variable is not informative about elections because there is a possibility that there are elections in a country but other autocratic characteristics dominate and thus

the score could be negative. We will discuss this bias in our results and analysis section. Hereafter we will refer polity 2 as autocracy democracy index or ADI. Figure 2 gives per-capita income for different values of autocracy-democracy index. In few case autocracies have higher income than democracies. We can see from Figure 3 that per-capita emission is also comparatively higher in autocracies. Figure 4 gives the relation between per-capita emission and per-capita income.

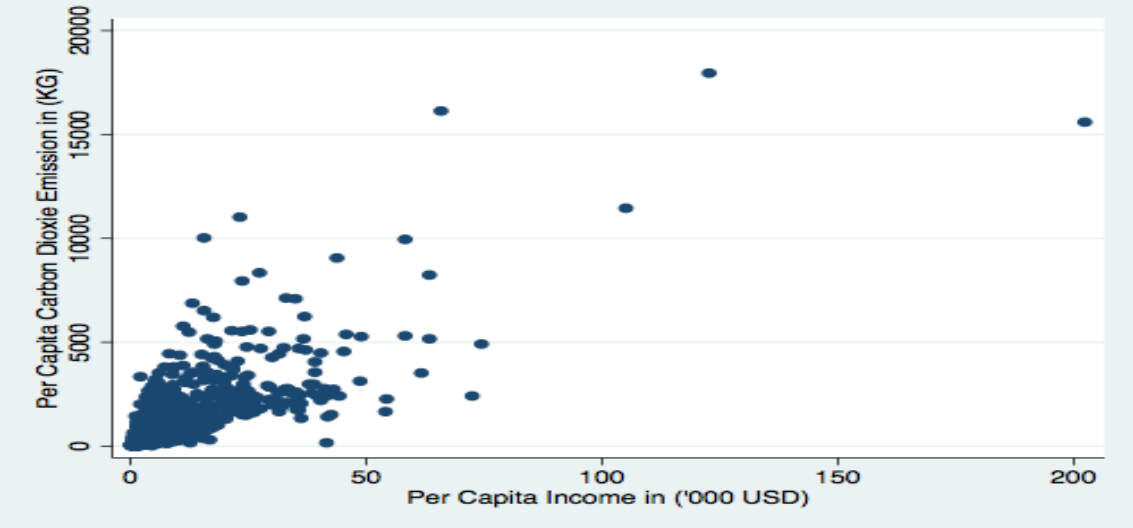


Figure 4: per-capita CO2 Emission and per-capita Income. Time Period; 1790-2010.

We use another institution variable "regimes of the world variable" from V-Dem (Lührmann et al., 2017) to explore the impact of elections on turning point, and as a measure of robustness. This index is available for the time period 1900 to 2010. It has four categories viz. closed autocracy, electoral autocracy, electoral democracy and liberal democracy. Electoral democracies have free and fair elections and represent multi-party democracies. Liberal democracy represents electoral democracy, and also incorporates liberal dimensions (score above 0.8 on the V-Dem liberal component index). They include transparent law enforcement and access to justice. Electoral autocracies have de-jure multiparty elections but fail to satisfy one or more characteristic of electoral democracy. Closed autocracies do not have even de-jure multiparty elections.

Trade data has been obtained from V-Dem. The original source for historical trade data is correlates of war project and is for time period 1880 and 2010 (Barbieri and Keshk, 2016). Trade to gross domestic product ratio has few high values (table 1) due to presence of countries like Luxembourg in our sample. We do robustness analysis to make sure that our results are not driven by presence of such outlier countries. Population data is obtained from V-Dem, and is available for the time period between 1950 and 2000. The original source for population data is Klein et al. (2010). Land data also comes from V-Dem and is derived from Haber and Menaldo (2011) and Weidmann et al. (2010). Dividing population with land area gives population density. Since population density is only available between 1950 and 2000, the extended EKC model with institution is estimated for 1950-2000. Figure 5 gives the number of countries for each decade being used in the estimations. The model that includes trade to GDP ratio is estimated with slightly lower number of countries as for few of them trade data is missing. Table 1 gives summary statistics of variables being used in estimation.

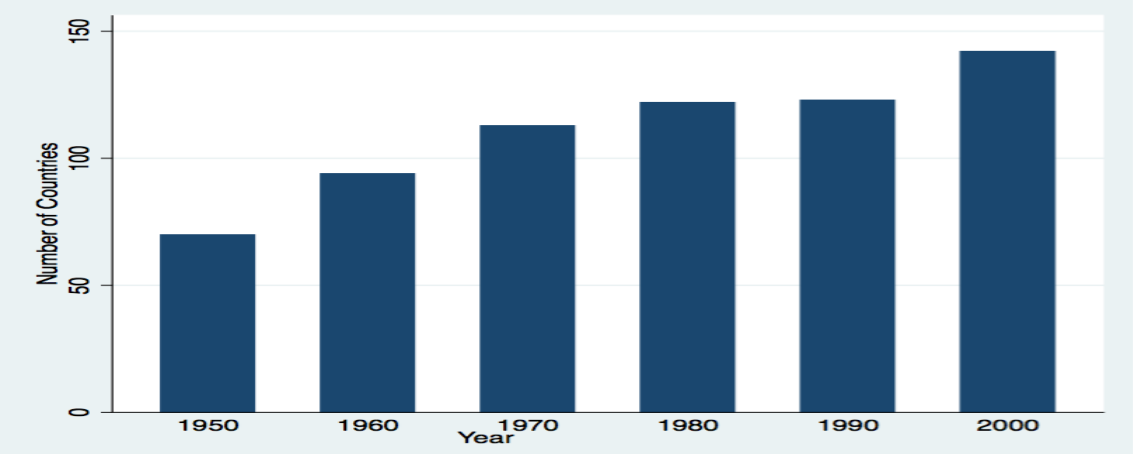


Figure 5: Year Wise Number of Countries For Extended EKC Model: Decadal Between 1950-2000

Table 1: Summary Statistics

| | per-capita CO2 Emission in (KG) | per-capita Income in ('000 USD) | Population Density | Trade GDP Ratio | Polity 2 |
|---|---|---|---|---|---|
| No of Observation | 1205 | 1205 | 693 | 846 | 1065 |
| Mean | 957.84 | 8.10 | 120.67 | 16.65 | 1.23 |
| Std. Dev. | 1580.80 | 12.41 | 428.52 | 82.68 | 7.23 |
| Minimum | 0.12 | 0.46 | 0.50 | 0.01 | -10.00 |
| Maximum | 17910.75 | 202.71 | 7275.26 | 1658.29 | 10.00 |

Notes: Population density is measured as no of people per square KM. Polity 2 is a categorical variable between -10 (total autocracy) to +10 (total democracy). Trade GDP ratio is in percentage.

# 4 Empirical Strategy

## 4.1 Simple Regression With Country Fixed Effects

The EKC hypothesis is formally represented as:

$$e_{it} = \theta_i + \theta_1 y_{it} + \theta_2 y_{it}^2 + \epsilon_{it} \tag{1}$$

Where $e_{it}$ is per-capita emission in country $i$ at time $t$, and $y_{it}$ is per-capita income in country $i$ at time $t$.[6] $\theta_i$ represent intercept for country $i$, also known as country fixed

[6]Schmalensee, Stoker, and Judson (1998) suggest that due to vast differences among countries, multiplicative country fixed effects are more plausible than additive effects. The multiplicative model is given by:

$$e_{it} = \theta_i \times y_{it}^{\theta_1} \times z_{it}^{\theta_2} \times \epsilon_{it} \tag{A}$$

Where $\theta_i$ are country fixed effects $y_{it}$ is income of country $i$ at time $t$ and for simplicity of notation we use $z_{it} = y_{it}^2$. Where we assume $E\left(\epsilon_{it}|y_{it}, z_{it}, \theta_i\right) = 1$ and that gives us:

$$E\left(e_{it}|y_{it}, z_{it}, \theta_i\right) = \theta_i \times y_{it}^{\theta_1} \times z_{it}^{\theta_2}$$

Taking natural logarithm of (A) leads to a log log specification given in (B).

$$ln\left(e_{it}\right) = ln\left(\theta_i\right) + \theta_1 ln\left(y_{it}\right) + \theta_2 ln\left(z_{it}\right) + ln\left(\epsilon_{it}\right) \tag{B}$$

The EKC model has been estimated with and without logarithm. Effectively this means a choice between model given by (A) which is multiplicative and a model given by (1) which is additive. Grossman and Krueger (1991) and Van Alistine and Neumayer (2010) use levels (not logarithms) to specify the

effects. We estimate basic pooled model as a robustness measure. Equation (1) implies that that rate of change of emission with respect to income, 'marginal emission intensity' (based on the idea of average q and marginal q)[7] depends upon the level of income.

$$\frac{de_{it}}{dy_{it}} = \theta_1 + 2 \times \theta_2 y_{it} \tag{2}$$

For EKC, the sign of $\theta_1$ is positive and the sign of $\theta_2$ is negative. Turning point $\left(\frac{-\theta_1}{2\theta_2}\right)$ is obtained by putting equation (2) equals to zero. In other words as countries grow richer they emit less for a unit increase in per-capita income. We expect better institutions will lead to lesser emission per unit change in per-capita income (lower marginal emission intensity). This is because more democratic institutions could lead to more environment friendly methods of economic activity owing to the demand for better environmental conditions. Suppose, we estimate the regression below to understand the impact of institution on emission:

$$e_{it} = \theta_i + \theta_1 y_{it} + \theta_2 y_{it}^2 + \theta_3 I_{it} + \epsilon_{it} \tag{3}$$

Where $I_{it}$ is the measure of institution in country $i$ at time $t$ . Equation (3) is not an appropriate specification as in this case the marginal emission intensity is independent of institution. This means the change in emission due to change in per-capita income does not depends upon institution. However, two countries with same income could emit

model. Holtz-Eakin and Selden (1995) examine both specifications and report no large differences. Consistency of estimates from (B) depends upon $ln\left(\epsilon_{it}\right)$ being uncorrelated with explanatory variable. Now suppose that the variance of $\epsilon_{it}$ depends upon the explanatory variable $\left(y_{it}\right)$ of the model (i.e. there is heteroscedasticity). This heterosceadstcity will lead to correlation between the error term and explanatory variable in multiplicative model because the expected value of the logarithm of a random variable depends both on its mean and on the higher-order moments of the distribution. In other words even if $E(y_{it}, \epsilon_{it})$ is 0; $E(ln\left(y_{it}\right), ln\left(\epsilon_{it}\right))$ may not be zero, Silva and Tenreyro (2006). Therefore, heteroscedasticity will translate into inconsistency if we estimate a model with log. Obviously dealing with heteroscedasticity is way easier that dealing the problem of inconsistency and therefore we estimate the model without log. For robustness, we check our results with log specification for few models and they give similar results as suggested by Holtz-Eakin and Selden (1995) and are reported in appendix.

[7] $\frac{e_{it}}{y_{it}}$ is average intensity and therefore $\frac{de_{it}}{dy_{it}}$ is called marginal emission intensity in this paper. This is similar to average q and marginal q. Tobin's q is the market value of the firm divided by its capital stock and thus is an average return on capital (known as average q). Marginal q is the change in the market value of a firm divided by the change in its capital stock (investment).

different amount of carbon-dioxide for an unit increase in income depending upon their level of institution. Therefore, we use an interaction effect of institution with income as given below:

$$e_{it} = \theta_i + \theta_1 y_{it} + \theta_2 y_{it}^2 + \theta_3 I_{it} + \theta_4 y_{it} \times I_{it} + \epsilon_{it} \tag{4}$$

In the model with the interaction of institution and per-capita income, the marginal emission intensity is given by:

$$\frac{de_{it}}{dy_{it}} = \theta_1 + 2 \times \theta_2 y_{it} + \theta_4 I_{it} \tag{5}$$

Equation (5) shows that a change in emission due to a unit change in per-capita income depends upon the per-capita income and institution. Thus, two countries with same per-capita income may have different level of emission for an unit increase in income because they have differences in institutions. If $\theta_4$ is negative that implies that a country with more democratic institution will emit less for a unit increase in per-capita income, given similar levels of per-capita income. In equation (2), the turning point depends upon only level of income but in equation (4), the turning point depends upon institution, and is given $\frac{-(\theta_1+\theta_4 I_{it})}{2\theta_2}$ (obtained by putting equation (5)= 0). In case of binary institution variable (0,1), the turning point is given by $\frac{-\theta_1}{2\theta_2}$ and $\frac{-\theta_1-\theta_4}{2\theta_2}$ for 0 and 1 respectively. The consequence of ignoring this interaction effect could be biased estimates.[8]

We estimate the model given by (4). One can argue that inclusion of $y_{it} \times I_{it}$ controls for non-linear relationship between pollution and income and therefore when we include $y_{it} \times I_{it}$, we should not include only $y_{it}^2$. But as we can see these two terms are controlling for fundamentally different things. If we do not include $y_{it}^2$ and only include $y_{it} \times I_{it}$, that will imply that marginal intensity depends upon $I_{it}$ only, but that is not true based on EKC hypothesis. Lv (2017) using data for 19 emerging economies suggests that democ-

[8]Suppose the true model is given by (4) and we estimate the equation given below:

$$e_{it} = \theta_i + \theta_1 y_{it} + \theta_2 y_{it}^2 + \theta_3 I_{it} + v_{it} \tag{6}$$

Now $v_{it} = \theta_4 I_{it} \times y_{it} + \epsilon_{it}$ and obviously all there variable of interest in (6) are correlated with $v_{it}$ i.e. $E(v_{it}, y_{it}) \neq 0$, $E(v_{it}, y_{it}^2) \neq 0$ and $E(v_{it}, I_{it}) \neq 0$. This implies that all these coefficients are biased as they did not satisfy the assumption that explanatory variable should be uncorrelated with error terms.

racy reduces emission in countries which has reached certain threshold level of income. Therefore, the study suggests that relationship between emission and political institution depends upon the level of income, giving empirical credence to the $y_{it} \times I_{it}$ being used in our empirical specification. Since, based on the economic rationale outlined above and the EKC hypothesis, we want marginal intensity to depend on both $y_{it}$ and $I_{it}$ and that can be achieved by including both $y_{it}^2$ and $y_{it} \times I_{it}$.

We augment the model given in equation (4) by using controls for population density, square of population density, and trade to gross domestic product (GDP) ratio. Population density has been found to be an important explanatory variable Panayotou (1997). Increase in population density should increase emission but as the population density increases there would be adaptation and mitigation too, giving us non-linear effects, and this justifies square of population density as used in Panayotou (1997). We include trade to GDP ratio based on pollution haven hypothesis. It has been argued that many developing countries are pollution haven due to lax environmental policies (Copeland and Taylor, 1995; Cole, 2004). As countries become richer, they outsource their polluting industries to poor countries and that leads to decline in pollution in richer countries but at the same time the pollution increases in poorer countries. Based on the above argument one can suggest that increasing trade share of gross domestic product increases pollution. At the same time, there is a possibility that the impact of trade on pollution depends upon the institutional arrangement in place. Better institutions could lead to less pollution with increasing trade to GDP ratio. In other words change in emission dues to an unit change trade to GDP ratio depends upon the institution. Thus, two countries identical in all respect except institution may have different level of emission for a unit increase in trade share because they have differences in institution.

$$e_{it} = \theta_i + \theta_1 y_{it} + \theta_2 y_{it}^2 + \theta_3 I_{it} + \theta_4 I_{it} \times y_{ti} + \theta_5 p_{it} + \theta_6 p_{it}^2 + \theta_7 t_{it} + \theta_8 t_{it} \times I_{it} + \epsilon_{it} \quad (7)$$

In equation (7), $p_{it}$ is population density in country $i$ at time $t$, and $t_{it}$ is trade to GDP ratio in country $i$ at time $t$. Our baseline measure of institution (ADI) has twenty one

categories and in the above regression it is used as a continuous variable.[9] Thereafter, we use ADI to make two meaningful categorical variable; one with three and other with four categories to have sufficient sample size.[10] This is done for two reasons, first, it allows us to compare the results obtained from ADI with regimes of the world data which has four categories, and second, it also allows us to substantiate the threshold ADI obtained from the threshold regression (discussed in the next section).

$$e_{it} = \theta_i + \theta_1 y_{it} + \theta_2 y_{it}^2 + \theta_3 I_{it} + \sum_{j=2}^{m} \theta_{4j} I_{j,it} \times y_{ti} + \theta_5 p_{it} + \theta_6 p_{it}^2 + \epsilon_{it} \quad \text{for } j = 3, 4 \quad (8)$$

Here, $I_{j,it}$ gives the institutional category $j$ in country $i$ at time $t$. The index on $j$ starts from 2 because the first category acts as a base category. The turning points for different categories are given by:

$$\text{Turning Point for Category } (1) = \frac{-\theta_1}{2\theta_2}$$

$$\text{Turning Point for Category } (j) = \frac{-\theta_1 - \theta_{4j}}{2\theta_2}$$

## 4.2 Threshold Regression With Country Fixed Effects

The model given by equation (7) excluding trade to GDP ratio is:

$$e_{it} = \theta_i + \theta_1 y_{it} + \theta_2 y_{it}^2 + \theta_3 I_{it} + \theta_4 I_{it} \times y_{ti} + \theta_5 p_{it} + \theta_6 p_{it}^2 + \epsilon_{it} \quad (9)$$

[9] $I_{it} \times y_{ti}$ is our variable of interest and $\theta_4$ is the coefficient of interest. If we will treat polity 2 as a categorical variable then we will have 20 coefficients of interest one for each category (one category would be base category). We are using omitted variable test of Oster (2019) to rule out the presence of omitted variable. This test is applicable for only one coefficient of interest and therefore we use polity 2 as continuous variable in our baseline regression. We do not think it is a bad assumption as polity 2 has 21 categories. Secondly using 21 categories will give us very few sample sizes for many categories for inference.

[10] We do not find trade to GDP ratio and interaction of trade to GDP ratio significant in (7) and therefore we drop them in further analysis.

From equation (9) we can see that $\frac{de_{it}}{dy_{it}} = \theta_1 + 2 \times \theta_2 y_{it} + \theta_4 I_{it}$. The marginal emission intensity depends upon income and institution. Equation (9) can be rewritten as follows:

$$e_{it} = \theta_i + (\theta_1 + \theta_4 I_{it} \times)\, y_{it} + \theta_2 y_{it}^2 + \theta_3 I_{it} + \theta_5 p_{it} + \theta_6 p_{it}^2 + \epsilon_{it} \tag{10}$$

$$e_{it} = \theta_i + (\theta\,(I_{it}))\, y_{it} + \theta_2 y_{it}^2 + \theta_3 I_{it} + \theta_5 p_{it} + \theta_6 p_{it}^2 + \epsilon_{it} \tag{11}$$

Here, we have assumed that coefficient associated with $y_{it}$ is a function of $I_{it}$ or depends upon $I_{it}$. The marginal emission intensity from equation (11) also depends upon the income and institution. The above model can be estimated using threshold regression framework.

$$e_{it} = \theta_i + \theta_{4,1} y_{ti}\,((I_{it}) < \gamma) + \theta_{4,2} y_{ti}\,((I_{it}) \geq \gamma) + \theta_2 y_{it}^2 + \theta_3 I_{it} + \theta_5 p_{it} + \theta_6 p_{it}^2 + \epsilon_{it} \tag{12}$$

Where $\theta_{4,1}$ and $\theta_{4,2}$ are coefficients associated with $y_{it}$ in two regimes based on $I_{it}$. Since coefficient associated wit $y_{it}$ varies in two regimes, turning point also varies in two regimes.[11]

$$\text{Turning Point in Regime } (1) = \frac{-\theta_{4,1}}{2\theta_2}$$

$$\text{Turning Point in Regime } (2) = \frac{-\theta_{4,2}}{2\theta_2}$$

[11]We estimate the model using Stata command "threshold" which is based on Gonzalo and Pitarakis (2002) with one threshold . Since, this command is for cross sectional regression we do fixed effect transformation (demean the country level variables) before estimation.

# 5 Results and Analysis:

## 5.1 Environmental Kuznets Curve

The baseline regression results are given in table 2. Model 1 is without country fixed effect and model 2 is with country fixed effects. In model 3 we include cubic per-capita income term and that does not turn out to be significant. Results validate EKC hypothesis (inverted U shape). As robustness exercise, table 13, 14 and 15 in appendix show the estimates using log specification and different time periods. These estimates also support the EKC hypothesis. Hereafter we use only per-capita income and square of per-capita income terms excluding the cubic term as it does not turn out to be significant. Figure: 6 gives marginal emission intensity $(\theta_1 + \theta_2 y)$ estimates from model 2. The intersection of the marginal emission intensity with $x$ axis occurs at 148000 USD which is the turning point. Our income is at current prices and therefore higher value of turning point is not puzzling.

Table 2: Environmental Kuznets Curve Estimation

| | (1) | (2) | (3) |
|---|---|---|---|
| | Model 1 | Model 2 | Model3 |
| per-capita Income | 110.8*** | 77.59*** | 114.9*** |
| | (0.000) | (0.000) | (0.000) |
| per-capita Income × per-capita Income | -0.144*** | -0.264*** | -1.314* |
| | (0.010) | (0.003) | (0.056) |
| per-capita Income × per-capita Income × per-capita Income | | | 0.00436 |
| | | | (0.107) |
| Constant | 92.13** | -133.8*** | -205.3*** |
| | (0.020) | (0.000) | (0.000) |
| $R^2$ | 0.601 | 0.853 | 0.861 |
| Observations | 1205 | 1205 | 1205 |
| Country Fixed Effects | No | Yes | Yes |

Notes: Models Estimated with Per-capita carbon-dioxide Emission. *, ** and *** denotes significance at 10, 5 and 1 percent respectively. Time Period; 1790-2010.

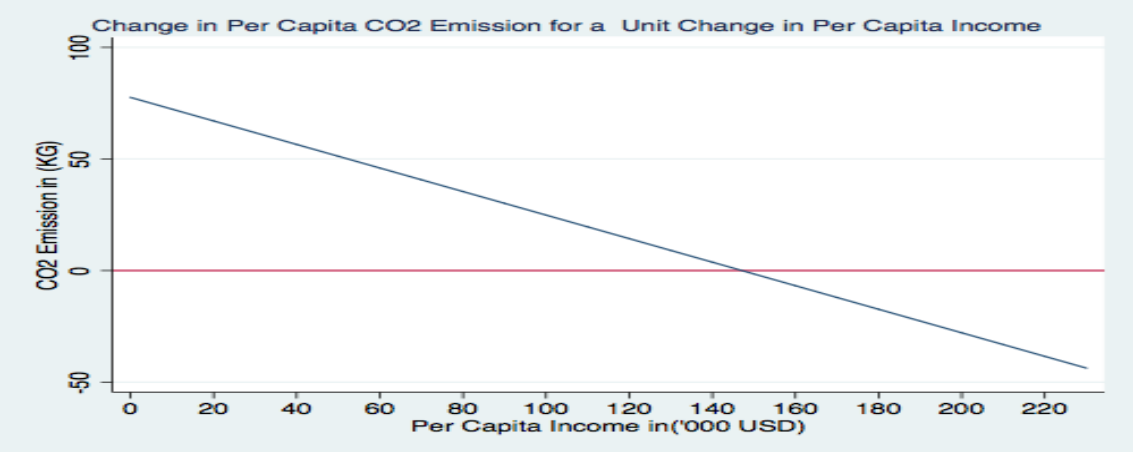


Figure 6: Turning Point From Equation $e_{it} = \theta_0 + \theta_1 y_{it} + \theta_2 y_{it}^2 + e_{it}$. The blue line represents $\frac{de_{it}}{dy_{it}} = \theta_1 + 2 \times \theta_2 y$ which is marginal emission intensity or change in emission for a unit change in per-capita income. The interesection with $x$ axis (red line) gives the income level for turning point which is equals to $\left(\frac{-\theta_1}{2\theta_2}\right)$. Turning point in ('000) USD at current prices. Time Period; 1790:2010.

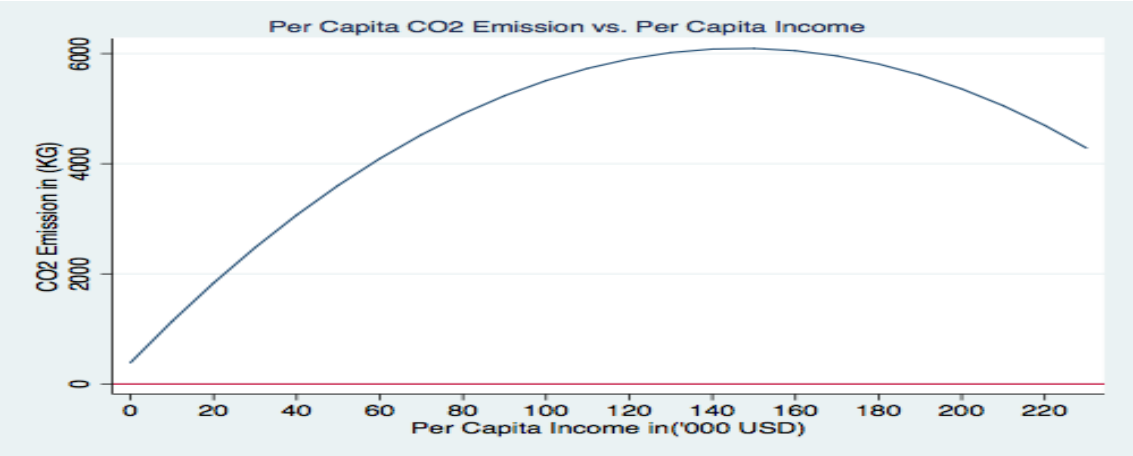


Figure 7: Predicted carbon-dioxide emission for given level of per-capita income. Turning point is at 148000 and per-capita carbon-dioxide emission starts falling after that with increase in per-capita income. Time Period; 1790:2010.

Figure 7 gives predicted carbon-dioxide from model 2 for given level of per-capita income.[12] As we can see from the figure, per-capita carbon-dioxide emission starts declining after the turning point (per-capita income of 148000). In the next section we explore the role of institution in changing this turning point which is the main objective of the paper. Lower turning point will imply that per-capita emission starts declining at lower level of income and thus leads to less total emission to reach a higher level of per-capita income.

## 5.2 Marginal Emission Intensity as Function of Political Institution

### 5.2.1 Simple Regression With Country Fixed Effects

Table 3 shows that marginal per-capita emission intensity depends upon the political institution (model 1) as interaction of ADI (autocracy democracy index) with per-capita income is significant. All models in table 3 validate the EKC hypothesis. Our coefficient of interest is in this analysis is the interaction of ADI with per-capita income. We are going to implement Oster (2019) for omitted variable test which is applicable for only one coefficient. Therefore, in this section we treat ADI as continuous variable for estimating models in table 3.

[12] We do not plot predicted emission hereafter as our interest lies in turning point which is depicted using figure 6.

Table 3: Estimated Per-capita carbon-dioxide emission (KG). Estimation of marginal emission intensity with Autocracy-Democracy index: OLS Regression

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
| per-capita Income in | 69.88*** | 96.11*** | 98.71*** | 97.32*** | 97.02*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| per-capita Income × per-capita Income | -0.225** | -0.425*** | -0.481*** | -0.471** | -0.468** |
| | (0.012) | (0.000) | (0.006) | (0.010) | (0.012) |
| Autocracy-Democracy Index | 12.68*** | 22.50*** | 20.87** | 22.10** | 22.22** |
| | (0.000) | (0.000) | (0.013) | (0.014) | (0.013) |
| Autocracy-Democracy Index × per-capita Income | | -2.473** | -4.402** | -4.298** | -4.262** |
| | | (0.028) | (0.023) | (0.036) | (0.040) |
| Population Density | | | 3.015*** | 3.047*** | 2.976*** |
| | | | (0.000) | (0.000) | (0.000) |
| Population-Density$^2$ | | -0.000313*** | -0.000314*** | -0.000309*** | |
| | | | (0.000) | (0.000) | (0.000) |
| Trade to GDP Ratio | | | | -0.330 | 0.296 |
| | | | | (0.730) | (0.522) |
| Trade to GDP Ratio × Autocracy-Democracy Index | | | | | -0.0705 |
| | | | | | (0.551) |
| $R^2$ | 0.875 | 0.880 | 0.924 | 0.925 | 0.925 |
| Observations | 1065 | 1065 | 664 | 621 | 621 |
| Observations | Yes | Yes | Yes | Yes | Yes |

Notes: Per-capita Income is in ('000 USD). Autocracy Democracy Index is represented by polity 2. *, ** and *** denotes significance at 10, 5 and 1 percent respectively. Number of observation varies as different explanatory variables are available for different time period. Time Period for Model 1 and 2 is 1800-2010. Time Period for Model 3, 4 and 5 is 1950-2000.

We use additional control variable such as population density (as in Panayotou (1997)) in model 3 but the interaction of ADI and per capita income remains significant, and the effect becomes even stronger. We also include trade to GDP (model 4) ratio based on the pollution haven hypothesis. However, we do not find evidence in support of pollution haven hypothesis as the coefficient of trade to GDP ratio is not significant. There is a possibility that the effect of trade on pollution depends upon political institution in place and to control for that we bring the interaction of trade with ADI as additional control in model 5. But the interaction and the trade to GDP ratio is not insignificant. Therefore, we do not include trade to GDP ratio in further analysis.

### 5.2.2 Threshold Regression with Country Fixed Effects

We estimate equation (12) with demeaned variable as explained above and results are given in table 4. Stata command used to estimate the threshold model is for cross sectional regression. Therefore we do fixed effect transformation (demean the country level variables) before estimation. Model 1 allows for the coefficient of $y_{it}$ as well as intercept to vary across regimes identified by ADI. Other coefficients such as of $y_{it}^2$, $p_{it}$, $p_{it}^2$ and $I_{it}$ remain constant across the two regimes. The estimated threshold for ADI is 1.2 in model 1. As we can see, for ADI $<$ 1.2 the coefficient associated with $y_{it}$ is 82.29 and beyond that this coefficient declines to 62.23. The turning points in two regimes are also different. With ADI $>$ 1.2, turning point is 40000 USD less in comparison to countries having ADI $<$ 1.2. Since the intercept in regime 2 is not significant in model 1, we estimate another model without intercept, the model also gives similar results and slightly higher value for threshold ADI.

Table 4: Estimation of marginal emission intensity with Autocracy-Democracy index: Threshold Regression

| Variable | Model 1 | Model 2 |
|---|---|---|
| per-capita Income × per-capita Income | $-0.25^{***}$ | $-0.25^{***}$ |
| Population Density | $2.896^{***}$ | $2.749^{***}$ |
| Population Density × Population Density | $-0.0003^{***}$ | $-0.0003^{***}$ |
| Autocracy-Democracy Index | $18.87^{**}$ | $18.87^{**}$ |
| per-capita Income Regime (1) | $82.29^{***}$ | $82.32^{***}$ |
| Constant Regime (1) | $157.43^{***}$ | |
| per-capita Income Regime (2) | $62.23^{***}$ | $65.90^{***}$ |
| Constant Regime (2) | $32.04$ | |
| Threshold Autocracy-Democracy Index | 1.2 | 2.5 |
| Turning Point Regime (1) | 164.5 | 164.6 |
| Turning Point Regime (2) | 124.6 | 131.8 |
| No of Observations | 664 | 664 |

Notes: Estimates obtained from $e_{it} = \theta_0 + \theta_{4,1} y_{ti} \left( (I_{it}) < \gamma \right) + \theta_{4,2} y_{ti} \left( (I_{it}) \geq \gamma \right) + \theta_2 y_{it}^2 + \theta_3 I_{it} + \theta_5 p_{it} + \theta_6 p_{it}^2 + \epsilon_{it}$. Models are Estimated with per-capita carbon-dioxide Emission which is in (KG). per-capita Income is in ('000 USD). Autocracy Democracy Index is represented by polity 2. popden is population density. *, ** and *** denotes significance at 10, 5 and 1 percent respectively. Regime (2) is beyond ADI score mentioned as threshold ADI score. Time Period; 1950-2000.

The above threshold regression suggest that institutions affects marginal emission intensity significantly. These results also suggest that there is significant threshold value of institution beyond which the impact of institution on turning becomes significant. Our main objective in this paper is to explore the role of institution in affecting carbon-dioxide emission through change in turning point. Therefore, based on above results, we drop trade and interaction of trade to GDP ratio with ADI and *use model 3* for further analysis.

$$e_{it} = \theta_0 + \theta_1 y_{it} + \theta_2 y_{it}^2 + \theta_3 I_{it} + \theta_4 I_{it} \times y_{ti} + \theta_5 p_{it} + \theta_6 p_{it}^2 + \epsilon_{it} \quad \text{(model 3)}$$

In the next section, we are going to test for omitted variable bias in the above specification and the possibility of outliers.

### 5.2.3 Evidence Against Omitted Variable Bias

As evident from the table 3, adding additional controls like trade to GDP ratio and interaction of trade to GDP ratio with ADI does not changes our coefficient of interest (interaction of ADI and per-capita income) much and $R^2$ of these models also do not change. One could argue that there are possible omitted variables in the model which might be giving the biased estimate of the coefficient of interest. A common approach in this case is to explore the sensitivity of the treatment effects to the inclusion of observed controls. If the coefficient is stable after inclusion of the observed controls, this is taken as a sign that omitted variable bias is limited (Oster, 2019). Since adding additional controls to Model 3 in table 3 does not changes our coefficient of interest much, we can say that the omitted variable is not driving this coefficient in significant way (Lacetera et al., 2012). But, simply looking at the stability of coefficient could be misleading if the observed and unobserved controls have different variance and thus different explanatory powers (Oster, 2019).

Oster (2019) building on Altonji et al. (2005) provides a test that computes the share of variation that omitted variables need to explain (relative to included control variables) to reduce the coefficient of interest to zero. This share is called $\delta$. If the test provide $\delta = 2$, that implies omitted variable needs to be twice as relevant as included controls to reduce the size of the coefficient of interest to zero. If one does not believe that omitted variables are twice as relevant as included variables, then it is safe to believe that the results are not driven by omitted variable bias. It is very unlikely to have $\delta > 1$ in reality as relevant controls would be included in the estimation. Implementation of the test requires $\hat{R}^2$ from a hypothetical regression in which all controls would be included (omitted ones too).[13] Since we do not observe this hypothetical regression, Oster (2019) recommends to use a $\hat{R}^2$ which is 1.3 times the $R^2$ of the estimated model with observed controls.

[13] Stata command "psacalc" is used to do implement the test

Table 5: Evidence Against Omitted Variable Bias

| Hypothesized $R^2$ ($\hat{R}^2$) | $\delta$ |
|---|---|
| 1 | 5.3 |
| .95 | 12.7 |
| .94 | 17.5 |
| .93 | 28.4 |

Notes: $\hat{R}^2$ gives the hypothesized $R^2$ with all controls (including omitted ones). $\delta$ represents required relative importance of omitted controls in comparsion to included controls that will turn the coefficient of interest (interaction of per-capita income with autocracy democracy index) insignificant.

In our estimation, the $R^2$ with the inclusion of relevant observed controls is .924 (model 3 in table 3). 1.3 times of that is greater than 1 and therefore we take the maximum value of hypothesized $R^2$ i.e. $\hat{R}^2$ as 1. As we can see from table 5 the required value of $\delta$ is 5.3 for $\hat{R}^2 = 1$. This implies that the omitted variables must be more that 5 times relevant in comparison to the included variables to turn the coefficient of interest insignificant. With a reasonable $\hat{R}^2 = .95$, the value of $\delta$ is 12.7. Therefore we conclude that omitted variables are not important enough to influence estimated coefficient of interest in a significant way. At the same time, we do not expect that ADI is influenced by the emission per-capita. Environmental regulation should respond to emissions, however, it is unlikely that political institutions will change due to emissions. Therefore we can say that the above regression is not likely to suffer from omitted variable bias and simultaneity.

### 5.2.4 Robustness: Outliers

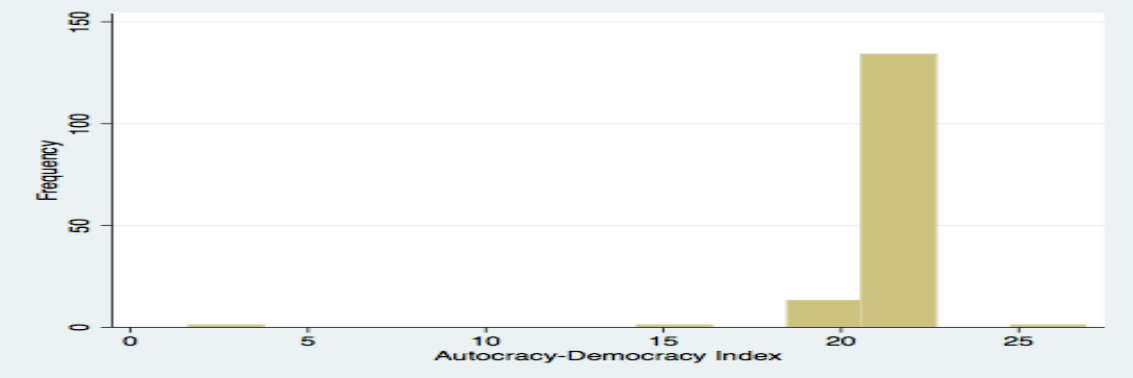


Figure 8: Coefficient of Autocracy-Democracy Index Obtained From Alternate Samples After Dropping One Country at a Time

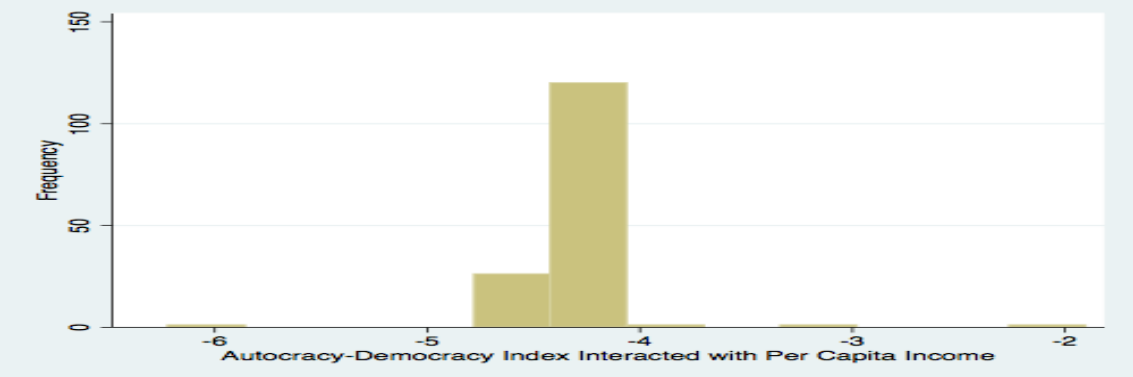


Figure 9: Coefficient of Autocracy-Democracy Index Interacted with per-capita Income Obtained From Alternate Samples After Dropping One Country at a Time

There is a possibility that our estimates are driven by outlier countries. To make sure that this is not the case, we drop one country each at a time and estimate model 3 of table 3. We store the coefficient of the ADI and interaction of ADI with per-capita income from each of these regressions and provide histogram of these. In figure 8 and 9, we provide the coefficient of ADI and the interaction term of ADI and per-capita income

for the above mentioned regressions. As we can see from figure 8 and 9, in more than 90 percent regressions our estimates of ADI and interaction of ADI with per-capita income come similar to one reported in model 3 in table 3. Out of a hundred and fifty regressions, in only three regressions, we get the coefficient of interaction of per-capita-income and ADI greater than the coefficient reported table 3, model 3. Therefore we conclude that marginal emission intensity depends upon the level of political institution in place (ADI). Political institution of the country significantly affect the turning point of environmental Kuznets curve. Hence, we have established that our estimates are not likely to suffer from omitted variable bias, simultaneity and presence of outliers.

## 5.3 Robustness with disaggregation of the regressor

To do a more intensive analysis about the role of institutions in affecting turning point with enough sample size, we create two measures from ADI. The first measure is a category variable named ADI.1 that is created as follows: ADI.1= 1 for ADI index $\geq -10$ and $\leq -5$ , ADI.1= 2 for ADI $> -5$ and $\leq 0$ , ADI.1= 3 $\text{for}$ADI $> 0$ and $<= 5$ is and ADI.1= 4 for ADI $> 5$ and $<= 10$. ADI.1=1 is the base group for comparison. We create another grouping ADI.2 for robustness; ADI.2= 1 for ADI $\leq -5$, ADI.2= 2 for ADI $> -5$ and $\leq 5$ and ADI.2= 3 for ADI $> 5$ .

Table 6: Marginal Emission Intensity and Autocracy Democracy Index Category

| | (1) Model 1 | (2) Model 2 |
|---|---|---|
| per-capita Income | 139.9*** | 139.3*** |
| | (0.000) | (0.000) |
| per-capita Income × per-capita Income | -0.469*** | -0.466*** |
| | (0.002) | (0.002) |
| Population Density | 3.080*** | 3.068*** |
| | (0.000) | (0.000) |
| Population Density × Population Density | -0.000331*** | -0.000324*** |
| | (0.000) | (0.000) |
| ADI.1=2 | 103.9 | |
| | (0.269) | |
| ADI.1=3 | 97.80 | |
| | (0.299) | |
| ADI.1=4 | 386.6*** | |
| | (0.008) | |
| ADI.1=2 × per-capita Income | -17.27 | |
| | (0.581) | |
| ADI.1=3 × per-capita Income | -37.49 | |
| | (0.208) | |
| ADI.1=4 × per-capita Income | -85.37*** | |
| | (0.007) | |
| ADI.2=2 | | 95.83 |
| | | (0.280) |
| ADI.2=3 | | 391.7*** |
| | | (0.007) |
| ADI.2=2 × per-capita Income | | -24.09 |
| | | (0.401) |
| ADI.2=3 × per-capita Income | | -84.82*** |
| | | (0.007) |
| Constant | -332.8*** | -331.3*** |
| | (0.000) | (0.000) |
| $R^2$ | 0.925 | 0.925 |
| Observations | 664 | 664 |
| Country Fixed Effects | Yes | Yes |

Notes: Models Estimated with per-capita carbon-dioxide Emission which is in (KG). per-capita Income is in ('000 USD). Autocracy Democracy Index is represented by polity 2. ADI.1 and ADI.2 are two groups created from ADI as explained in the text. *, ** and *** denotes significance at 10, 5 and 1 percent respectively. Time Period; 1950-2000.

Table 7: Turning Point Estimates: Categories of Autocracy-Democracy Index

| Four Categories | | | Three Categories | | |
|---|---|---|---|---|---|
| Variable | Coefficient | Turning Point (PCI) | Variable | Coefficient | Turning Point(PCI) |
| PCI | $139.9^{***}$ | | PCI | $139.3^{***}$ | |
| PCI $\times$ PCI | $-0.469^{***}$ | | PCI$\times$ PCI | $-0.466^{***}$ | |
| ADI.1 $= 1 \times$ PCI | $0$ | $149.6$ | ADI.2 $= 1 \times$ PCI | $0$ | $149.1$ |
| ADI.1 $= 2 \times$ PCI | $-17.27$ | $149.6$ | ADI.2 $= 2 \times$ PCI | $-24.09$ | $149.1$ |
| ADI.1 $= 3 \times$ PCI | $-37.49$ | $149.6$ | ADI.2 $= 3 \times$ PCI | $-84.82^{***}$ | $58.1$ |
| ADI.1 $= 4 \times$ PCI | $-85.37^{**}$ | $57$ | | | |

Notes: PCI is per-capita income. *, ** and *** denotes significance at 10, 5 and 1 percent respectively. Turning points in ('000) USD at current prices. Turning points for ADI.1=2 and ADI.1=3 remains same as turning point for ADI.1=1 because the interaction of ADI.1=2 and ADI.1=3 with per-capita income is not significant. Similarly turning point for ADI.2=2 remains same as turning point for ADI.2=1. Time Period; 1950-2000.

We estimate separate regression models using these two types of institutional category, as shown in table: 6. Evidence in favor of EKC hypothesis continues to hold. As we can see from table 6, with the institutional category ADI.1 (4 categories), only category four (ADI.1= 4) interaction with per-capita income turns out to be significant (model 1). Similarly, in case of ADI.2, only interaction of category 3 (ADI.2= 3) with per capita income turns out to be significant (model 2). Category 1 is same in both these grouping. Category four in first regression is same as category 3 in second regression. The turning point for each institutional category from these two estimates are are given in table 7. Figure 10 and 11 in appendix show these turning points graphically.

Table 16 in appendix give estimates of the model 1 of table 6 using log specification. Table 17 in appendix give estimates of the model 1 of table 6 with time trend. Time trend does not turns out to be significant. Our omitted variable bias test in previous section suggested that this specification is not likely to suffer from omitted variable bias. Therefore, the insignificance of the time trend is not surprising. Thus, we conclude that our result is not likely to suffer from omitted variable bias, simultaneity, presence of outliers and wrong functional form. Since, it can be argued that change in institution will have some time lag in its affect on emission, we estimate the model 1 of table 6 using lagged value of ADI. Table 18 in appendix shows the estimates from the same. Results are similar except that now we have interaction of ADI.1=3 with per-capita income com-

ing out to be significant. Table 19 in appendix gives the estimates of turning points for different ADI categories from this regression.

Based on table 7, we conclude that the turning point for ADI between -10 to - 5 (category 1 in both regressions) is significantly different from ADI between 5 to 10 which is category 4 in first regression and category 3 in second regression. Comparison of turning point suggest that the turning point in case of countries having ADI $\leq$ 5 is more than 2.5 times of the turning point for countries having ADI $>$ 5. This means that emission due to a unit change in per-capita income starts declining at much higher level of income in countries having ADI $\leq$ 5 in comparison to countries having ADI $>$ 5. In the next section, we estimate the model with institutional measure from regimes of the world data and and then compare these two sets of turning points.

Table 19 in appendix gives the estimates of turning points for different ADI categories from regression with lagged ADI. Comparison of turning point suggest that the turning point in case of countries having ADI $\leq$ 0 is more than 2.5 times of the turning point for countries having ADI $>$ 5. Countries with ADI$>$0 and ADI $\leq 5$ have turning point lower than countries with ADI $\leq$ 0 but greater than the turning point of countries with ADI $>$ 5.

## 5.4 Political Institution and Turning Point: Robustness

Table 8: Marginal Emission Intensity and Regimes of the World

| | (1) |
|---|---|
| | Per-capita Carbon Dioxie Emission in (KG) |
| Per-capita Income | 148.6*** |
| | (0.000) |
| Per-capita Income × per-capita Income | -0.501*** |
| | (0.001) |
| Population Density | 2.826*** |
| | (0.000) |
| Population Density × Population Density | -0.000273*** |
| | (0.000) |
| Electoral Autocracy | 167.6** |
| | (0.036) |
| Electoral Democracy | 157.3 |
| | (0.145) |
| Liberal Democracy | 963.7*** |
| | (0.001) |
| Electoral Autocracy × per-capita Income | -68.24*** |
| | (0.005) |
| Electoral Democracy × per-capita Income | -68.93** |
| | (0.017) |
| Liberal Democracy × per-capita Income | -101.5*** |
| | (0.002) |
| $R^2$ | 0.929 |
| Observations | 662 |
| Country Fixed Effects | Yes |

Notes: Models Estimated with per-capita carbon-dioxide Emission which is in (KG). per-capita Income is in ('000 USD). *, ** and *** denotes significance at 10, 5 and 1 percent respectively. Time Period; 1950-2000.

As a robustness, we use another data for institutional category available in V-Dem database. The regimes of world data has four categories, closed autocracy, electoral

autocracy, electoral democracy and liberal democracy.[14] The regression results are given in table 8. Evidence in favor of EKC hypothesis continues to hold. As we can see from the results of model 1, all three institutional category interacted with per-capita income are significant. The coefficient associated with interaction of electoral autocracy and electoral democracy interacted with per capita income is similar and thus the turning point for these two categories are similar.

The turning point is given in table 9 for all four categories. Figure 12 in appendix show turning points graphically. The results suggest that election makes a significant difference in turning point as turning point for electoral autocracy and electoral democracy are significantly lower to the turning point for closed autocracy. Our turning point for liberal democracy are similar to the fourth category turning point obtained from ADI. The turning point obtained for closed autocracy is very similar to the turning point of first category obtained from ADI.

Table 9: Turning Point Estimates: Four Categories from Regimes of the World

| Variable | Coefficient | Institutional Category | Turning Point |
|---|---|---|---|
| per-capita Income | $148.6^{***}$ | | |
| per-capita Income $\times$ per-capita Income | $-0.501^{***}$ | | |
| Closed Autocracy $\times$ per-capita Income | $0$ | Closed Autocracy | $148.3$ |
| Electoral Autocracy $\times$ per-capita Income | $-68.24^{***}$ | Electoral Autocracy | $80.2$ |
| Electoral Democracy $\times$ per-capita Income | $-68.93^{**}$ | Electoral Democracy | $79.50$ |
| Liberal Democracy $\times$ per-capita Income | $-101.5^{***}$ | Liberal Democracy | $47$ |

Notes: *, ** and *** denotes significance at 10, 5 and 1 percent respectively. Turning points in ('000) USD at current prices. Time Period; 1950-2000.

[14]We cannot use this variable for omitted variable test as there are three coefficients of interest with this.

## 5.5 Reconciling Turning Points from Autocracy-Democracy Index and Regimes of the World

These two measures of institutions (ADI and regimes of the world) are not directly comparable.[15] We have 962 observations for which both of these indicators exist and have been given in table: 10. ADI.1= 1 is made up of autocracies both closed as well as electoral autocracy but mostly closed autocracies. ADI.1= 2 and 3 are similar because they both contain most of electoral autocracy and individually they have lesser number of electoral autocracy than in ADI.1= 1. ADI.1= 1, 2 and 3, three of them together have most of autocracies (both closed and electoral) and very few democracies. This is the reason we do not get significantly different turning point for ADI.1=1, 2 and 3.[16] ADI.1= 4 contain most of democracies both electoral and liberal and thus we get significantly different turning point for ADI.1= 4 in comparison to ADI.1=1, 2 and 3. Broadly, the difference in turning point obtained from ADI categories is difference in turning points for autocracies and democracies.

Since our ADI.1= 4 consist of both electoral and liberal democracy. It gives a turning point of 58000 USD whereas the regimes of the world data makes distinction between electoral and liberal democracy and gives turning point of 79500 and 47000 USD respectively. Based on the distinction between electoral democracy and liberal democracy this decline in turning point in liberal democracy in comparison to electoral democracy can be attributed to liberal component, transparent law enforcement and access to justice.

Our ADI category is also not able to tease out the impact of election because ADI.1=1, 2 and 3 *contains most of autocracies (both closed and electoral). Electoral autocracies*

[15]At this point, we would like to clarify that we did not use only regimes of the world data, as this will give three coefficient of interest. Oster (2019) methodology is applicable for only one coefficient of interest and we can not do omitted variable test. Therefore we started with ADI and provided evidence against omitted variable bias. After establishing the fact that the impact of institution on turning point is not likely to suffer from omitted variable bias and simultaneity, we brought other measure of institution for robustness and exploring the impact of elections on turning point.

[16]With one period lagged value of ADI we get statistically different turning point for ADI.1=1, 2 and ADI.1= 3 (see table 19 in appendix). Since, this result is obtained with a smaller sample, we do not attempt to compare these turning points with turning points obtained from regimes of the world data.

*are almost in equal number in these three ADI categories.* On the other hand, regimes of the world data makes distinction between closed autocracy, electoral autocracy and electoral democracy and therefore captures the impact of election in changing turning points. As shown in table 9, electoral autocracy and electoral democracy have almost same turning points and therefore it implies that elections are important for turning point but have similar impact in autocracy and democracy.

Table 10: Autocracy-Democracy Index and Regimes of the World

| Autocracy-Democracy Index | Regimes of the World | | | | |
|---|---|---|---|---|---|
| ADI.1 | Closed Autocracy | Electoral Autocracy | Electoral Democracy | Liberal Democracy | Total |
| 1 | 224 | 91 | 0 | 0 | 315 |
| 2 | 44 | 74 | 7 | 0 | 125 |
| 3 | 24 | 78 | 10 | 3 | 115 |
| 4 | 10 | 50 | 140 | 207 | 407 |
| Total | 302 | 293 | 157 | 210 | 962 |

Notes: The first measure is a category variable named dummy that is created as follows: ADI.1=1 for ADI index $- \geq 10$ and $\leq -5$, ADI.1=2 for ADI $> -5$ and $\leq 0$ , ADI.1=3 for ADI $> 0$ and $\leq 5$ is and ADI.1=2 for ADI $> 5$. Regimes of the world has four categories as mentioned before.

## 5.6 Further Robustness

In this section we provide further evidence of impact of institutions on turning point. We use three dichotomous regime classifications (0 for autocracy, 1 for democracy). The first one is from Cheibub, Gandhi, and Vreeland (2010), and the second one is from Boix, Miller, and Rosato (2012). We call them CGV and BMR respectively. Third measure is from Acemoglu et al. (2019). Acemoglu et al. (2019) use data from Freedom House, Polity IV, CGV and BMR to construct their dichotomous regime. This is represented as ANRR. Details about construction of ANRR democracy index is given in Acemoglu et al. (2019). These three additional measures of democracy index are available between 1960 and 2010. Therefore, our regressions are with lesser number of observations. Regression results are given in table: 11. Evidence in favor of EKC hypothesis continues to hold. The interaction of democracy index with per-capita income has expected sign as argued in section 2. Model 4 gives the estimates obtained with ANRR index after dropping countries which transition to and from democracy.

Table 11: Effect of Institution Using Additional Democracy Index

| | (1) Model 1 | (2) Model 2 | (3) Model 3 | (4) Model 4 |
|---|---|---|---|---|
| per-capita Income | 126.4*** | 121.3*** | 123.3*** | 122.9*** |
| | (0.001) | (0.002) | (0.001) | (0.002) |
| per-capita Income in × per-capita Income in | -0.412** | -0.392** | -0.400** | -0.398** |
| | (0.012) | (0.017) | (0.015) | (0.019) |
| popden | 3.482*** | 3.304** | 3.403*** | 3.494** |
| | (0.006) | (0.012) | (0.009) | (0.016) |
| popden × popden | -0.00147 | -0.00130 | -0.00140 | -0.00148 |
| | (0.160) | (0.212) | (0.177) | (0.192) |
| Democracy measure by BMR | 423.4*** | | | |
| | (0.006) | | | |
| Democracy measure by BMR × per-capita Income | -84.93** | | | |
| | (0.010) | | | |
| Democracy measure by CGV | | 387.6*** | | |
| | | (0.009) | | |
| Democracy measure by CGV × per-capita Income | | -79.94** | | |
| | | (0.016) | | |
| Democracy measure by ANRR | | | 369.7** | |
| | | | (0.013) | |
| Democracy measure by ANRR × per-capita Income | | | -81.71** | |
| | | | (0.014) | |
| Democracy measure by ANRR | | | | 431.7*** |
| | | | | (0.009) |
| Democracy measure by ANRR × per-capita Income | | | | -81.81** |
| | | | | (0.018) |
| Constant | -305.7*** | -291.5*** | -297.7*** | -299.0*** |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| $R^2$ | 0.923 | 0.922 | 0.922 | 0.921 |
| Observations | 588 | 586 | 588 | 511 |
| Country Flxed Effects | Yes | Yes | Yes | Yes |

Notes: popden is population density. Model 3 and Model 4 both use ANRR measure of institution. Model 4 is estimated with countries having always autocracy or democracy. In other words we drop those countries which shows transition from autocracy to democracy and democracy to autocracy. Number of observation varies as different explanatory variables are available for different time period. Time Period; 1960-2000.

Table 12: Turning Point Estimates: Other Democracy Indices

| Variable | Coefficient | Coefficient | Coefficient | Coefficient | Turning Point Democracy | Turning Point Autocracy |
|---|---|---|---|---|---|---|
| per-capita Income | $126.4^{***}$ | $121.3^{***}$ | $123.3^{***}$ | $122.9^{***}$ | | |
| per-capita Income × per-capita Income | $-0.412^{**}$ | $-0.392^{**}$ | $-0.40^{**}$ | $-0.398^{**}$ | | |
| BMR × per-capita Incom | $-84.93^{**}$ | | | | 50 | 153 |
| CGV × per-capita Income in | | $-79.94^{**}$ | | | 53 | 155 |
| ANRR × per-capita Income | | | $-81.71^{**}$ | | 52 | 154 |
| ANRR × per-capita Income$^{+}$ | | | | $-81.71^{**}$ | 52 | 154 |

Notes: *, ** and *** denotes significance at 10, 5 and 1 percent respectively. Turning points in ('000) USD at current prices. Turning point for autocracy and democracy is obtained by putting the value of respective index 0 and 1. + denotes the turning point obtained with ANRR index after dropping countries which transition to and from democracy. Time Period; 1960-2000.

As we can see from the table: 12, these democracy indices gives similar turning points. Turning point in autocracy is roughly three times of the turning point in democracy. This results holds even after dropping countries which transition to and from democracy. Figure 13-16 in appendix shows these turning points graphically.

# 6 Concluding Remarks

The results obtained in this paper validate the EKC hypothesis for carbon-dioxide emission for 150 countries over the time period 1790-2010. The hypothesis continues to hold in several extended model estimated in the paper for time period 1950-2000 and 1960-2000. When marginal emission intensity is defined as change in emission for an unit change in per-capita income, both simple as well threshold regression with country fixed effects analysis show that the marginal emission intensity depends upon prevailing institutions (value of autocracy and democracy index). Dependence of marginal emission intensity on institution implies that institutions matter for the turning point of EKC and thus affect the quality of the environment.

Our analysis suggests that autocracies have significantly higher turning points, and that they emit more carbon-dioxide for a unit change in per-capita income than democracies. In comparison to democracies, emission due to a unit change in per-capita income starts declining at much higher levels of income in autocracies. In other words, autoc-

racies emits more carbon-dioxide to reach the same level of per-capita income vis-a-vis democracy. These estimates are not driven by the presence of outlier countries as our estimates are robust to elimination of possible outlier countries. These estimates are also not likely to suffer from wrong functional form and simultaneity bias. This is because we do not expect emission to influence institution contemporaneously. Any effect of emission on institution is expected to have some time lag.

In the environmental Kuznets curve literature, the impact of institutions on the turning point estimates have been criticized due to the possibility of omitted variable bias which makes these effects non-causal. Our study fills this gap in the existing literature by formally testing the possibility of omitted variable bias using methodology of Oster (2019).[17] The methodology allows us to include most relevant variables found in literature as explanatory variables. Therefore, it is highly unlikely that significance and the sign of the institution coefficient is biased due to omitted variable. Therefore, this paper contributes to the literature by providing near causal effect of institution on emission. . Using regimes of the world data, we show that elections matter for emissions. Turning point for electoral autocracies are less than that of closed autocracies. At the same time there is no differential impact of elections on turning point in autocracies and democracies. But liberal democracies have additional positive differences in comparison to electoral democracies. This could be attributed to the transparent rule enforcement and access to justice potentially lowering the turning point of the EKC in case of liberal democracy. Therefore, improving rule enforcement and access to justice can help in decreasing the carbon-dioxide emissions and could increase the environmental quality.

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# Appendix

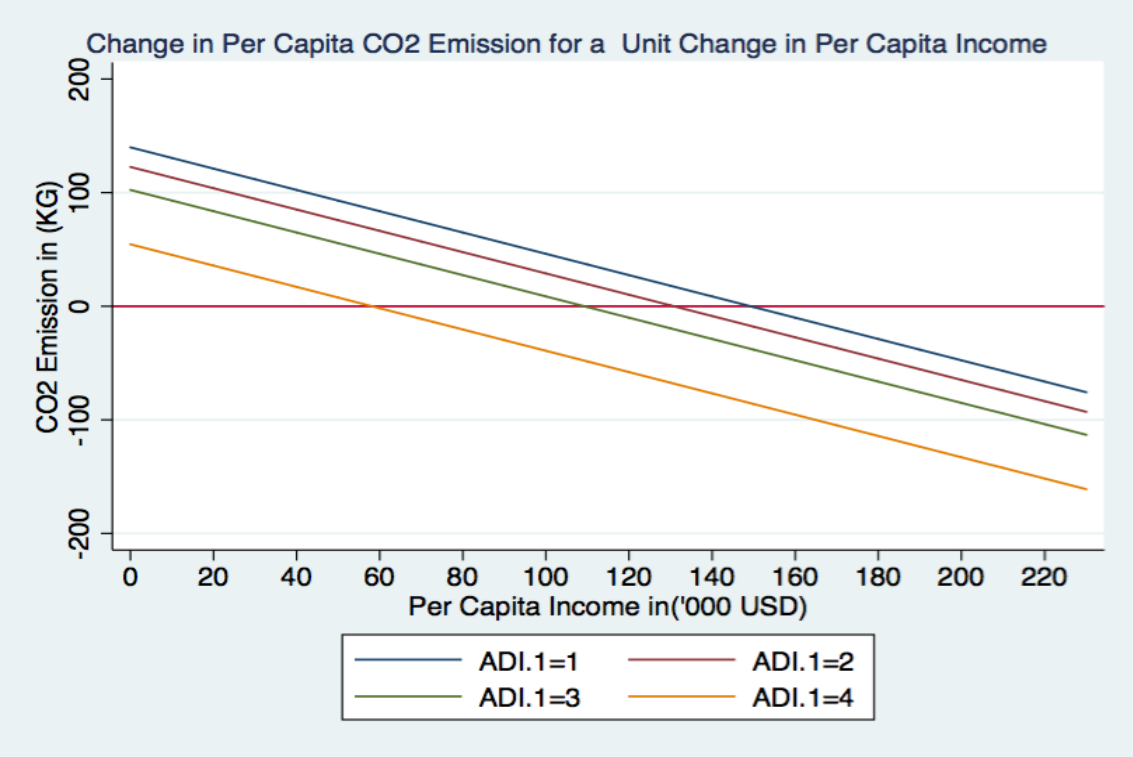


Figure 10: Turning Point From Equation $e_{it} = \theta_0 + \theta_1 y_{it} + \theta_2 y_{it}^2 + \theta_3 I_{it} + \sum_{j=2}^{4} \theta_{4j} I_{j,it} \times y_{ti} + \theta_5 p_{it} + \theta_6 p_{it}^2 + \epsilon_{it}$. $I_{j,it}$ are four categories created from 21 categories of polity 2. Lines represent marginal emission intensity or change in emission for a unit change in per-capita income. The interesection with $x$ axis (red line) gives the income level for turning point which is equals to $\left(\frac{-\theta_1}{2\theta_2}\right)$ for category 1 given by ADI.1=1. For catgeory $j = 2, 3, 4$ the turning point is given by $\frac{-\theta_1 - \theta_{4j} \times I_{j,it}}{2\theta_2}$ which is shown as ADI.1=2, ADI.1=3 and ADI.1=4 respectively. Turning point in ('000) USD at current prices. Time Period; 1950-2000.

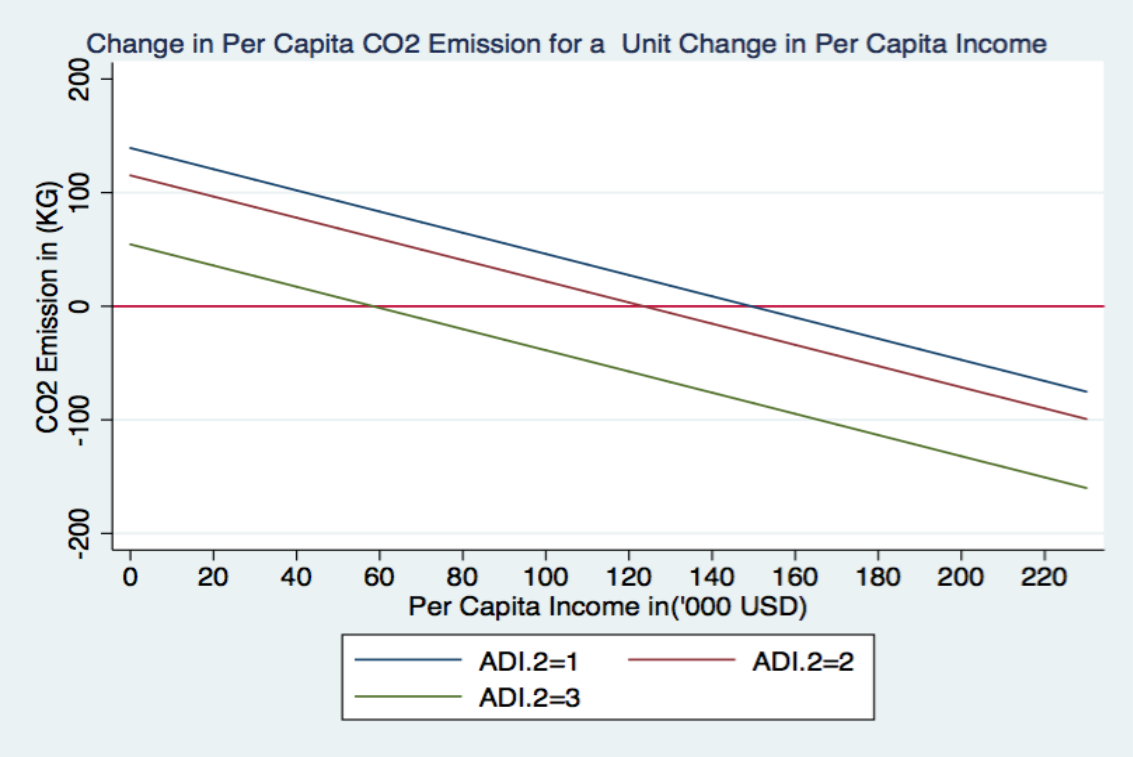


Figure 11: Turning Point From Equation $e_{it} = \theta_0 + \theta_1 y_{it} + \theta_2 y_{it}^2 + \theta_3 I_{it} + \sum_{j=2}^{3} \theta_{4j} I_{j,it} \times y_{ti} + \theta_5 p_{it} + \theta_6 p_{it}^2 + \epsilon_{it}$. $I_{j,it}$ are three categories created from 21 categories of polity 2. Lines represent marginal emission intensity or change in emission for a unit change in per-capita income. The interesection with $x$ axis gives the income level for turning point which is equals to $\left(\frac{-\theta_1}{2\theta_2}\right)$ for category 1 (ADI.2=1). For catgeory $j = 2, 3$ the turning point is given by $\frac{-\theta_1 - \theta_{4j} \times I_{j,it}}{2\theta_2}$ which is shown as ADI.2=2, ADI.2=3 respectively. Turning point in ('000) USD at current prices. Time Period; 1950-2000.

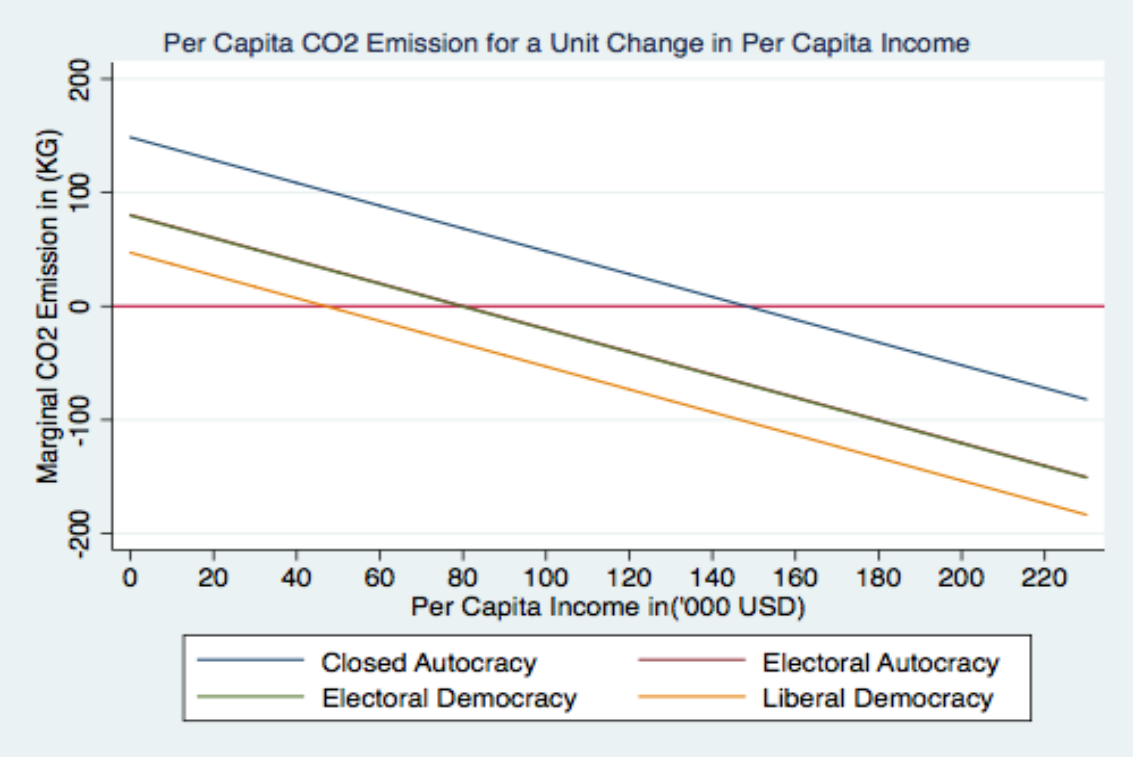


Figure 12: Turning Point From Equation $e_{it} = \theta_0 + \theta_1 y_{it} + \theta_2 y_{it}^2 + \theta_3 I_{it} + \sum_{j=1}^{3} \theta_{4j} I_{j,it} \times y_{ti} + \theta_5 p_{it} + \theta_6 p_{it}^2 + \epsilon_{it}$. $I_{j,it}$ is data from Regimes of the world which is a categorical variable. 0: Closed autocracy: 1: Electoral autocracy 2: Electoral democracy 3: Liberal democracy. Lines represent marginal emission intensity or change in emission for a unit change in per-capita income. The interesection with $x$ axis gives the income level for turning point which is equals to $\left(\frac{-\theta_1}{2\theta_2}\right)$ for category 0 (closed autocracy). For catgeory $j = 1, 2, 3$ the turning point is given by $\frac{-\theta_1 - \theta_{4j} \times I_{j,it}}{2\theta_2}$. Turning points in ('000) USD at current prices. Time Period; 1950-2000.

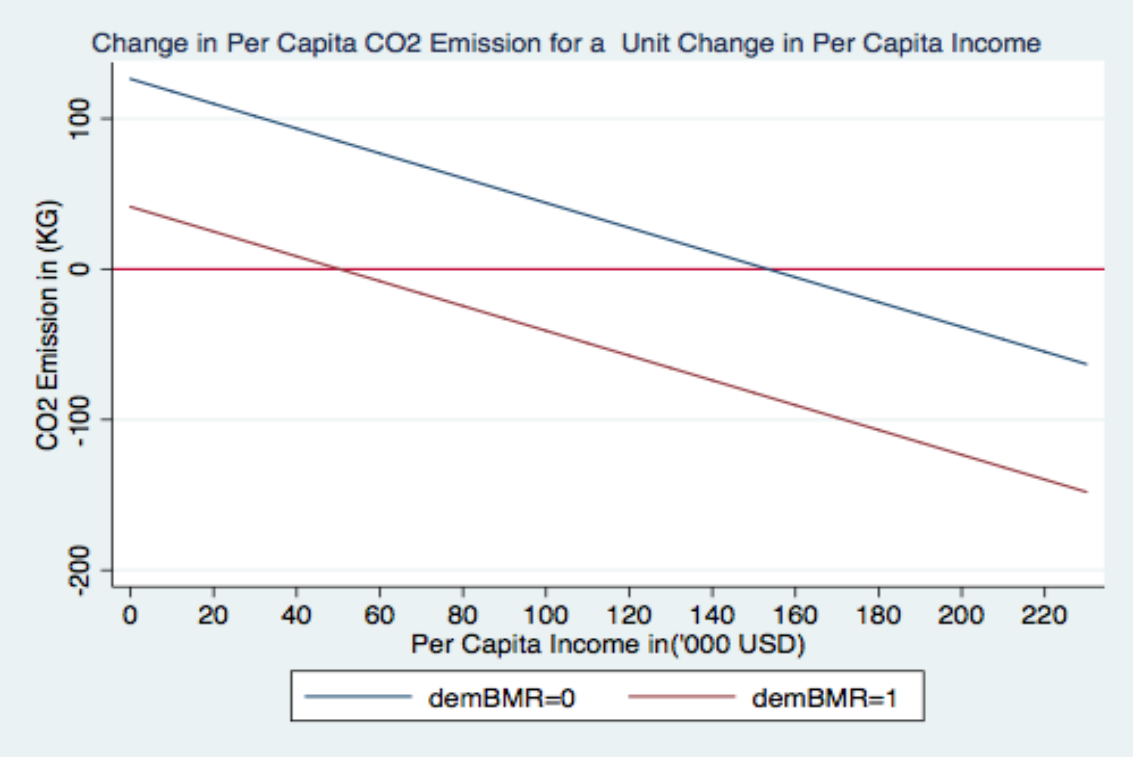


Figure 13: Turning Point From Equation $e_{it} = \theta_0 + \theta_1 y_{it} + \theta_2 y_{it}^2 + \theta_3 I_{it} + \theta_4 I_{it} \times y_{ti} + \theta_5 p_{it} + \theta_6 p_{it}^2 + \epsilon_{it}.I_{it}$ is BMR for democracy. Lines represent marginal emission intensity or change in emission for a unit change in per-capita income. The interesection with $x$ axis gives the income level for turning point which is equals to $\left(\frac{-\theta_1}{2\theta_2}\right)$ for category 0 (demBMR=0, autocracy). For democracy (demBMR=1) the turning point is given by $\frac{-\theta_1-\theta_4}{2\theta_2}$. Turning points in ('000) USD at current prices. Time Period; 1960-2000.

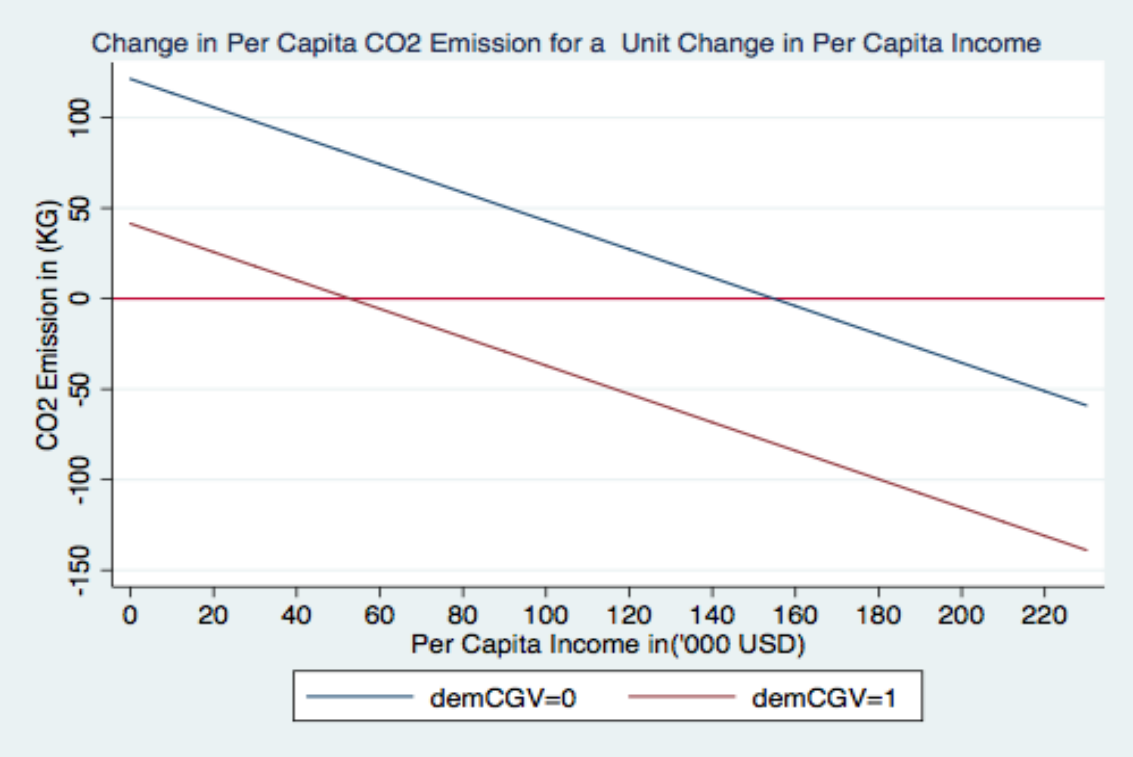


Figure 14: Turning Point From Equation $e_{it} = \theta_0 + \theta_1 y_{it} + \theta_2 y_{it}^2 + \theta_3 I_{it} + \theta_4 I_{it} \times y_{ti} + \theta_5 p_{it} + \theta_6 p_{it}^2 + \epsilon_{it}$. $I_{it}$ is CGV index for democracy. Lines represent marginal emission intensity or change in emission for a unit change in per-capita income. The interesection with $x$ axis gives the income level for turning point which is equals to $\left(\frac{-\theta_1}{2\theta_2}\right)$ for category 0 (demCGV=0,autocracy). For democracy (demCGV=1) the turning point is given by $\frac{-\theta_1-\theta_4}{2\theta_2}$. Turning points in ('000) USD at current prices. Time Period; 1960-2000.

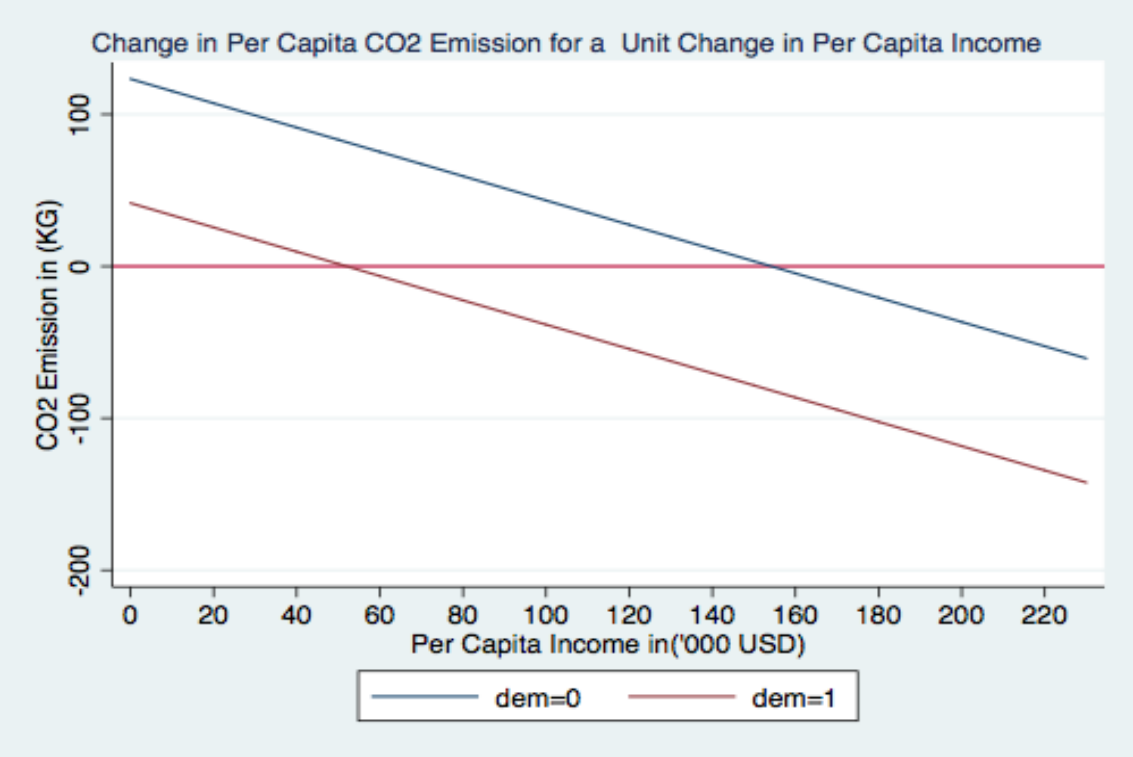


Figure 15: Turning Point From Equation $e_{it} = \theta_0 + \theta_1 y_{it} + \theta_2 y_{it}^2 + \theta_3 I_{it} + \theta_4 I_{it} \times y_{ti} + \theta_5 p_{it} + \theta_6 p_{it}^2 + \epsilon_{it}$. $I_{it}$ is ANRR index for democracy. Lines represent marginal emission intensity or change in emission for a unit change in per-capita income. The interesection with $x$ axis gives the income level for turning point which is equals to $\left(\frac{-\theta_1}{2\theta_2}\right)$ for category 0 (dem=0, autocracy). For democracy (dem=1) the turning point is given by $\frac{-\theta_1 - \theta_4}{2\theta_2}$. Turning points in ('000) USD at current prices. Time Period; 1960-2000.

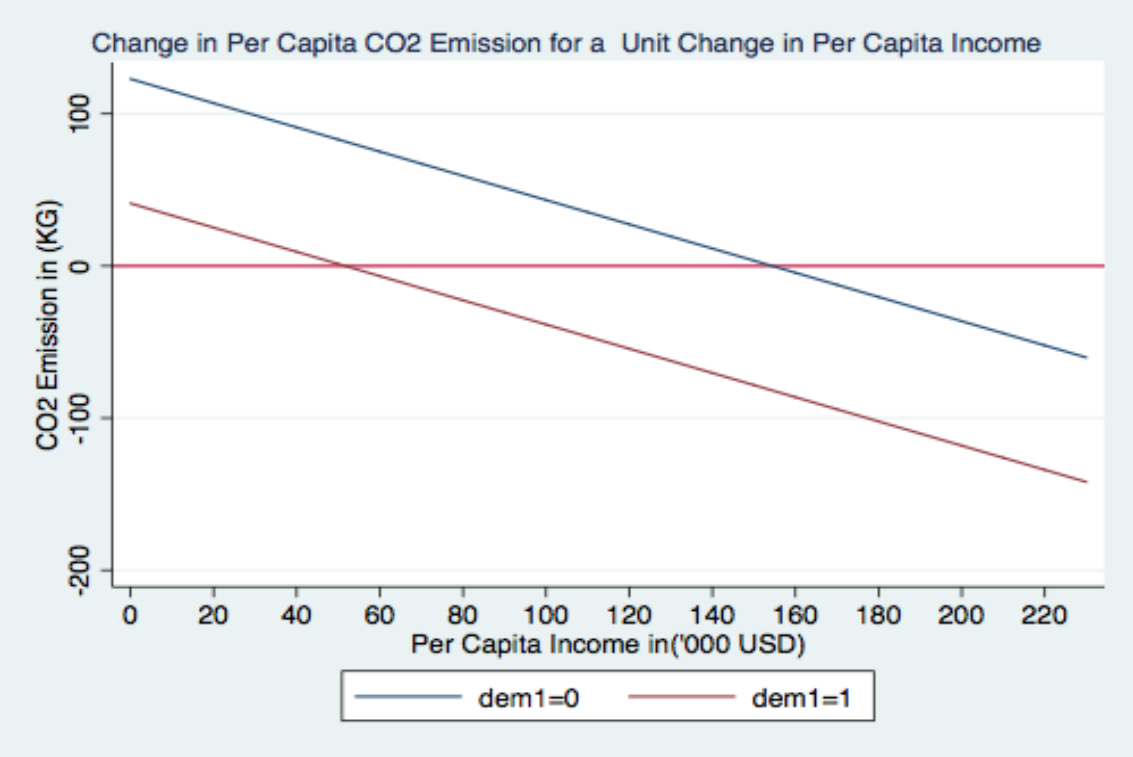


Figure 16: Turning Point From Equation $e_{it} = \theta_0 + \theta_1 y_{it} + \theta_2 y_{it}^2 + \theta_3 I_{it} + \theta_4 I_{it} \times y_{ti} + \theta_5 p_{it} + \theta_6 p_{it}^2 + \epsilon_{it}$. $I_{it}$ is ANRR index for democracy. Lines represent marginal emission intensity or change in emission for a unit change in per-capita income. The interesection with $x$ axis gives the income level for turning point which is equals to $\left(\frac{-\theta_1}{2\theta_2}\right)$ for category 0 (dem=0, autocracy). For democracy (dem1=1) the turning point is given by $\frac{-\theta_1 - \theta_4}{2\theta_2}$. Countries with transition to and from democracy dropped. Turning points in ('000) USD at current prices. Time Period; 1960-2000.

# Robustness

Table 13: Environmental Kuznets Curve Estimation: Log Specification

| | (1) Model 1 | (2) Model 2 | (3) Model 3 |
|---|---|---|---|
| per-capita Income | 2.083*** | 2.181*** | 2.084*** |
| | (0.000) | (0.000) | (0.000) |
| per-capita Income × per-capita Income | -0.199*** | -0.271*** | -0.196* |
| | (0.000) | (0.000) | (0.055) |
| per-capita Income × per-capita Income × per-capita Income | | | -0.0142 |
| | | | (0.391) |
| Constant | 3.244*** | 1.511*** | 1.535*** |
| | (0.000) | (0.002) | (0.001) |
| $R^2$ | 0.691 | 0.853 | 0.853 |
| Observations | 1205 | 1205 | 1205 |
| Country Fixed Effects | No | Yes | Yes |

Notes: Models Estimated with per-capita carbon-dioxide Emission. Both per-capita carbon-dioxide Emission and per-capita Income in Natural Logarithm. *, ** and *** denotes significance at 10, 5 and 1 percent respectively. Time Period; 1790-2010.

Table 14: Environmental Kuznets Curve Estimation: Log Specification

| | (1) Model 1 | (2) Model 2 | (3) Model 3 |
|---|---|---|---|
| per-capita Income | 1.914*** | 1.424*** | 1.310*** |
| | (0.000) | (0.000) | (0.000) |
| per-capita Income × per-capita Income | -0.155*** | -0.153*** | -0.0669 |
| | (0.000) | (0.000) | (0.512) |
| per-capita Income × per-capita Income × per-capita Income | | | -0.0154 |
| | | | (0.318) |
| Constant | 3.285*** | 1.927*** | 1.958*** |
| | (0.000) | (0.000) | (0.000) |
| $R^2$ | 0.748 | 0.921 | 0.921 |
| Observations | 912 | 912 | 912 |
| Country Fixed Effects | No | Yes | Yes |

Notes: Models Estimated with per-capita carbon-dioxide Emission. Both per-capita carbon-dioxide Emission and per-capita Income in Natural Logarithm. *, ** and *** denotes significance at 10, 5 and 1 percent respectively. Time Period; 1950-2010.

Table 15: Environmental Kuznets Curve Estimation: Log Specification

| | (1) Model 1 | (2) Model 2 | (3) Model 3 |
|---|---|---|---|
| per-capita Income | 1.889*** | 1.591*** | 1.415*** |
| | (0.000) | (0.000) | (0.000) |
| per-capita Income × per-capita Income | -0.142*** | -0.166*** | -0.0332 |
| | (0.000) | (0.000) | (0.807) |
| per-capita Income × per-capita Income × per-capita Income | | | -0.0239 |
| | | | (0.257) |
| Constant | 3.383*** | 1.812*** | 1.852*** |
| | (0.000) | (0.003) | (0.002) |
| $R^2$ | 0.737 | 0.927 | 0.928 |
| Observations | 664 | 664 | 664 |
| Country Fixed Effects | No | Yes | Yes |

Notes: Models Estimated with per-capita carbon-dioxide Emission. Both per-capita carbon-dioxide Emission and per-capita Income in Natural Logarithm. *, ** and *** denotes significance at 10, 5 and 1 percent respectively. Time Period; 1950-2000.

Table 16: Marginal Emission Intensity and Autocracy Democracy Index Category: Model with Log Specification

| | (1) |
|---|---|
| | per-capita Carbon Dioxie Emission in (KG) |
| per-capita Income | 1.495*** |
| | (0.000) |
| per-capita Income × per-capita Income | -0.126*** |
| | (0.001) |
| Population Density | 0.00336*** |
| | (0.000) |
| Population Density × Population Density | -0.000000333*** |
| | (0.000) |
| ADI.1=2 | 0.260* |
| | (0.081) |
| ADI.1=3 | -0.0475 |
| | (0.801) |
| ADI.1=4 | 0.410*** |
| | (0.002) |
| ADI.1=2 × per-capita Income | -0.188* |
| | (0.095) |
| ADI.1=3 × per-capita Income | -0.0778 |
| | (0.589) |
| ADI.1=4 × per-capita Income | -0.242** |
| | (0.011) |
| Constant | 1.776*** |
| | (0.003) |
| $R^2$ | 0.933 |
| Observations | 664 |
| Country Fixed Effects | Yes |

Notes: Models Estimated with per-capita carbon-dioxide Emission. Both per-capita carbon-dioxide Emission and per-capita Income in Natural Logarithm. Autocracy Democracy Index is represented by polity 2. ADI.1 and ADI.2 are two groups created from ADI as explained in the text. *, ** and *** denotes significance at 10, 5 and 1 percent respectively. Time Period; 1950-2000.

Table 17: Marginal Emission Intensity and Autocracy Democracy Index Category: Model with Time Trend Specification

| | (1) |
|---|---|
| | per-capita Carbon Dioxie Emission in (KG) |
| per-capita Income | 132.7*** |
| | (0.001) |
| per-capita Income × per-capita Income | -0.438*** |
| | (0.007) |
| Population Density | 2.574*** |
| | (0.000) |
| Population Density × Population Density | -0.000277*** |
| | (0.000) |
| ADI.1=2 | 98.21 |
| | (0.317) |
| ADI.1=3 | 92.20 |
| | (0.342) |
| ADI.1=4 | 319.5* |
| | (0.052) |
| ADI.1=2 × per-capita Income | -21.23 |
| | (0.500) |
| ADI.1=3 × per-capita Income | -43.42 |
| | (0.117) |
| ADI.1=4 × per-capita Income in | -85.01*** |
| | (0.007) |
| Time Trend | 37.59 |
| | (0.186) |
| Constant | -472.4*** |
| | (0.000) |
| $R^2$ | 0.925 |
| Observations | 664 |
| Country Fixed Effects | Yes |

Notes: Models Estimated with per-capita carbon-dioxide Emission. Autocracy Democracy Index is represented by polity 2. ADI.1 from ADI as explained in the text. *, ** and *** denotes significance at 10, 5 and 1 percent respectively. Time Period; 1950-2000.

Table 18: Marginal Emission Intensity and Autocracy Democracy Index Category: Model with Lagged Autocracy Democracy Index

| | (1) |
|---|---|
| | per-capita Carbon Dioxie Emission in (KG) |
| per-capita Income | 169.6*** |
| | (0.000) |
| per-capita Income × per-capita Income | -0.874*** |
| | (0.000) |
| Population Density | 1.915** |
| | (0.045) |
| Population Density × Population Density | -0.000240*** |
| | (0.008) |
| ADI.1=2 | 198.2 |
| | (0.207) |
| ADI.1=3 | 255.3 |
| | (0.122) |
| ADI.1=4 | 675.9*** |
| | (0.000) |
| ADI.1=2 × per-capita Income in | -27.07 |
| | (0.406) |
| ADI.1=3 × per-capita Income | -79.96*** |
| | (0.007) |
| ADI.1=4 × per-capita Income | -106.9*** |
| | (0.000) |
| Constant | -354.8 |
| | (0.173) |
| $R^2$ | 0.928 |
| Observations | 521 |

Notes: Models Estimated with per-capita carbon-dioxide Emission. Autocracy Democracy Index is represented by polity 2 which is shown as ADI. ADI.2, ADI.3 and ADI.4 are groups created from ADI as explained in the text. All models estimated with one lag of ADI values. *, ** and *** denotes significance at 10, 5 and 1 percent respectively. Time Period; 1950-2000.

Table 19: Turning Point Estimates: Lagged Autocracy Democracy Index Categories

| Four Categories | | |
|---|---|---|
| Variable | Coefficient | Turning Point (PCI) |
| PCI | $169.6^{***}$ | |
| PCI $\times$ PCI | $-0.874^{***}$ | |
| ADI.1 $= 1 \times$ PCI | $0$ | $194.05$ |
| ADI.1 $= 2 \times$ PCI | $-27.07$ | $194.05$ |
| ADI.1 $= 3 \times$ PCI | $-79.96^{***}$ | $102.56$ |
| ADI.1 $= 4 \times$ PCI | $-106.9^{***}$ | $71.74$ |

Notes: PCI is per-capita income. *, ** and *** denotes significance at 10, 5 and 1 percent respectively. Turning points in ('000) USD at current prices. Turning points for ADI.1=2 remains same as turning point for ADI.1=1 because the interaction of ADI.1=2 with per-capita income is not significant. Time Period; 1950-2000.