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Corruption, Inequality, and Environmental Regulation

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Abstract

We develop two public choice models in which environmental regulation is determined endogenously in the presence of agents who are heterogenous in wealth or income. In the first model, regulation is determined by a majority vote, and an increase in inequality induces an increase in environmental standard. In the second model, the environmental standard is chosen by a corrupt bureaucrat. In that model, while the impact of an increase in inequality on the environmental standard is uncertain, a higher level of corruption always reduces the quality of environmental regulation. An empirical analysis using cross-country data confirms the implication of both models.

Keywords: Environmental regulation, corruption, inequality
JEL Codes: Q560, Q580

*This paper is a substantially modified version of Makdissi and Wodon (2003).

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1 Introduction

The problem of the determination of environmental standards has been studied from various angles. One area of research focuses on the impact of competition between juridictions when firms are mobile. This has been studied among others by Oates and Schwab (1988), Markusen, Morey and Orweiler (1993, 1995), Motta and Thisse (1994), Wellisch (1995), Levinson (1997), Glazer (1999) and Tanguay and Marceau (2001). As noted by Hoel (1997), the models are somewhat inconclusive since firm mobility and competition between juridictions may lead to emissions levels which are too high or too low depending on the assumptions used. Applied works in this line of research include Levinson (1996) and List and Co (2000).

Another area of research, which is closer to our own work in this paper, relates to the political economy of the determination of environmental standards, and specifically to the impact of corruption. As pointed out by Damania (2002), the problem is particularly important in developing countries where corruption may undermine sound policy. Previous theoretical analysis include Fredricksson (1997a, b, 1999), Damania (1999), López and Mitra (2000) and Fredricksson and Svensson (2003). Empirical analysis have also been performed by Damania, Fredriksson and List (2003), Fredriksson, Vollebergh and Dijkgraaf (2004) and Pellegrini (2006).

In this paper, we focus on the interaction between corruption and inequality, and on the impact of both variables on environmental regulation. To do so, we build on a paper by Barrett (1994) showing that even if firms are not mobile, jurisdictions still have an incentive to use environmental policy strategically in order to increase the national firm's profit in an international duopoly. This idea is similar to Spencer and Brander's (1983) analysis of Reseach and Development subsidies and Brander and Spencer's (1985) analysis of export subsidies.

More specifically, we develop two public choice models in which environmental regulation is determined endogenously in the presence of agents who are heterogenous in wealth or income. In both models, the utility of the agents depends on profits and on the quality of the environment, as measured by environmental regulation as a proxy for pollution or emissions.

The difference between the two models lies in the presence or absence of corruption.

In the model without corruption, regulation is determined by a majority vote. An increase in wealth or income inequality induces an increase in the environmental standard, essentially because a high level of inequality means that most agents do not share much in the firm's profits, so that a majority of the agents will gain from imposing stricter environmental standards. That is, although the median voter will use environmental regulation as a strategic variable in order to increase the national firm's profits, the utility gain from a cleaner environment will be a more important factor in his/her decision.

In the second model, in the presence of corruption, the environmental standard is chosen by a corrupt bureaucrat. Bribing the bureaucrat becomes a public good in the view of firm shareholders, since lower environmental standards imply higher profits. In this context, an increase in wealth inequality reduces the free rider problem among shareholders and reduces the environmental standard.

Using data on environmental regulation, corruption, inequality, and a number of other variables, we perform an econometric analysis which seems to indicate that both models are consistent with observed behavior. First, we see a direct impact of inequality on the level of environmental regulation. Second, we show that in presence of corruption, countries with higher inequality place a lower premium on the environment.

The rest of the paper runs as follow. Section 2 presents the basic structure of the model. Section 3 analyzes the impact of wealth or income inequality (and international competition) on environmental regulation under a majority voting framework. Section 4 performs the same analysis assuming that environmental standards are fixed by corrupt bureaucrats. Finally, Section 5 tests the implications of the two models using cross-country data on environmental regulation. A brief conclusion follows.

2 The Basic Model

Our model uses the duopoly framework proposed by Barret (1994). We assume that each firm is located in a different country. In producing y^i units, the firm in country i emits a local pollutant z^i. Following Barret (1994), we assume that the good produced by the two firms is not consumed in any of the two countries. This implies that the only benefit from a reduction in the environment standard in country i is an increase in the national firm's profit. In this context, the profit π^i for the firm in country i is given by

$$\pi^i = r^i \left(y^1, y^2\right) - c^i \left(y^i\right) - e^i \left(y^i, z^i\right) \tag{1}$$

where $r^i (y^1, y^2)$, $c^i (y^i)$, $e^i (y^i, z^i)$ represent respectively the firm's revenue, its production costs, and its environmental epuration costs. We assume that $r^i_j < 0$, $c^i_y > 0$, $e^i_y > 0$, $e^i_z \leq 0$ and $e^i_{zy} \leq 0$.

Country i is populated with n^i agents who differ only in their income or wealth, which depends on their share of the national firm. The share of agent k in the national firm's capital is denoted by ψ^i_k, with $\sum_k \psi^i_k = 1$, for $i = 1, 2$. The preferences of the agents are represented by a quasi-linear utility function

$$u^i_k \left(\pi^i, z^i\right) = \psi^i_k \pi^i - \phi \left(z^i\right) \tag{2}$$

where $\phi' (\cdot) > 0$ and $\phi'' (\cdot) > 0$.

The game has two stages. In the first stage, the environmental standard is chosen. We will consider two possibilities for the determination of this standard, namely a majority vote and a standard chosen by a bureaucrat who may be corrupted by the firm's owners. In the second stage, the two firms (denoted by 1 and 2) choose their output.

In order to find a backward solution, we first solve for the second stage. At this stage, environmental regulation is taken as given, and denoted by $\overline{z}^i$. The Cournot-Nash equilibrium for the duopoly is given by the solution to:

$$\max_{y^i} r^i \left(y^1, y^2\right) - c^i \left(y^i\right) - e^i \left(y^i, \overline{z}^i\right) \quad \text{for } i = 1, 2. \tag{3}$$

Denoting when needed by a subscript i a partial derivative with respect to y^i, by a subsript ii the second order partial derivative, and by ij a cross partial derivative, the first and second order conditions are

$$r^i_i - c^i_y - e^i_y = 0, \quad \text{for } i = 1, 2. \tag{4}$$

$$r^i_{ii} - c^i_{yy} - e^i_{yy} < 0 \quad \text{for } i = 1, 2.$$

In order to have a stable equilibrium, we assume that $r^i_{ij} < 0$ and that $\pi^1_{11}\pi^2_{22} - \pi^1_{12}\pi^2_{21} > 0$.

3 Environmental Regulation Under Majority Voting

In this section, we assume that the environmental standard is fixed by majority voting at the first stage of the game. Each agent who owns one or more shares in the national firm has an incentive to lower the environmental standard in order to increase profits. Hence, the environmental standard is used as a strategic variable by the voters. In making his/her choice, each agent considers the reaction of the voters in the other country.

The choice of the environmental standard z^i_k by agent k in country i is given by the solution to:

$$\max_{z^i_k} \psi^i_k \pi^i \left(y^1, y^2, z^i_k\right) - \phi\left(z^i_k\right) \tag{5}$$

subject to

$$r^i_i - c^i_y - e^i_y = 0,$$

$$r^j_j - c^j_y - e^j_y = 0.$$

Maximization behavior of the agent implies:

$$\psi^i_k \left[\pi^i_i \frac{\partial y^i}{\partial z^i} + \pi^i_j \frac{\partial y^j}{\partial y^i}\frac{\partial y^i}{\partial z^i} - e^i_z\right] - \phi_z = 0. \tag{6}$$

Profit maximization implies that $\pi^i_i = 0$. Furthermore, $u^i_k\left(\pi^i, z^i\right)$ is strictly concave in z^i, which implies that this function is unimodal. In this context, we can use the median voter theorem which state that the Condorcet winner of a majority vote in this kind of framework is the choice of the median voter M_i. The environmental standard is then given by

$$\psi^i_{Mi} \left[\pi^i_j \frac{\partial y^j}{\partial y^i}\frac{\partial y^i}{\partial z^i} - e^i_z\right] - \phi_z = 0. \tag{7}$$

The first stage of the game is equivalent to a situation where the median voters in each country choose simualtenously the environmental standards by anticipating the Cournot-Nash equilibrium at the second stage of the game. Note that if each agent has an equal share of the national firm or if, at least, the median voter has a share equal to $1/n^i$, the result of the game is equivalent to Barret(1994) the optimal level of pollution at the national level.

In order to have a stable equilibrium we must assume that

$$\frac{\partial^2 u^i_{Mi}}{\partial y_i^2}\frac{\partial^2 u^i_{Mi}}{\partial z^2} - \frac{\partial^2 u^i_{Mi}}{\partial y_i \partial z}\frac{\partial^2 u^i_{Mi}}{\partial z \partial y_i^2} > 0 \tag{8}$$

and

$$\frac{\partial^2 u^i_{Mi}}{\partial y_i^2}\frac{\partial^2 u^j_{Mj}}{\partial y_i \partial z}\frac{\partial^2 u^j_{Mj}}{\partial z \partial y_i} + \frac{\partial^2 u^i_{Mi}}{\partial y_i \partial y_j}\frac{\partial^2 u^j_{Mj}}{\partial y_j \partial y_i}\frac{\partial^2 u^j_{Mj}}{\partial z^2} - \frac{\partial^2 u^i_{Mi}}{\partial y_i^2}\frac{\partial^2 u^j_{Mj}}{\partial y_j^2}\frac{\partial^2 u^j_{Mj}}{\partial z^2} > 0. \tag{9}$$

Proposition 1 *The Nash equilibirum of the game* $(\widehat{z}^1, \widehat{z}^2, \widehat{y}^1, \widehat{y}^2)$ *is implicitely defined by (4) and (7) for* $i = 1$ *and* 2.

Inspection of equation (7) reveals that the environmental standard is negatively correlated with the median voter's share of firm's profit. The lowest value for the environmental standard is obtained when income or wealth is equally distributed (we assume that wealth distribution is skewed to the left). As soon as the median voter has a share of the firm $\psi^i_{Mi} < 1/n_i$, the environmental standard becomes more stringent. More generally, we have $dz^i\left(\psi^i_{Mi}\right)/d\psi^i_{Mi} \geq 0$. This means that a lower share of the national firm by the median voter induces an increase in the environmental standard, essentially because a high level of inequality means that most agents do not share much in the firm's profits, so that a majority of the agents will gain from imposing stricter environmental standards.

4 Environmental Regulation With Corrupt Bureaucrats

In this section, we assume that the environmental standard in each country is chosen by a bureaucrat who may be corrupted. In absence of corruption, the bureaucrat choses the environmental standard according to the result of a majority vote. This means that he choses the level of emissions that is prefered by the median voter. But in the presence of corruption, the outcome will be different. In order to perform this analysis, we assume that an agent may pay a bribe $B = b^i\Delta^i$ to the bureaucrat in order to induce him to fix a lower level of environmental regulation. The per unit price of lower regulation is represented by b^i and $\Delta^i = \widetilde{z}^i - \widehat{z}^i$ represents the difference between the actual level of regulation and the level that the bureaucrat would be expected to choose if he/she were not corrupt.

We assume that the firm cannot pay bribes and, as in Damania (2002), we also assume that there is a probability θ_i that a successful audit will be initiated, leading to a sanction for the bureaucrat. Let $S_i(\Delta^i)$ represent a money-metric of the disutility of the sanction imposed, with $S_i'(\cdot) > 0$ and $S_i''(\cdot) \geq 0$. For simplicity, we assume that the bureaucrat is not risk averse, so that he/she simply maximizes expected income. Let w denote the bureaucrat's income without corruption. Under corruption, the expected gain from corruption (EGC) for the bureaucrat is

$$EGC = \underbrace{w + b^i\Delta^i - \theta_i S_i\left(\Delta^i\right)}_{\substack{\text{Income}\\\text{with}\\\text{corruption}}} - \underbrace{w}_{\substack{\text{Income}\\\text{without}\\\text{corruption}}} \tag{10}$$

Maximization behaviour of the bureaucrat implies

$$\theta_i S_i'\left(\Delta^i\right) = b^i \tag{11}$$

This means that the bureaucrat increases the level of emissions or polution (reduces the environmental standard) if the marginal increase in expected disutility (in monetary terms) is lower than the marginal dollar of bribe he/she receives. From (11), it is clear that if the probability of detection, θ_i, decreases or if the marginal disutility of the penalty decreases, the level of emissions or polution will be higher (the regulation will be weaker). We can thus expect to find a positive correlation between the level of emissions and the level of corruption in a country, or put differently, a negative correlation between the level of environmental regulation and corruption.

Proposition 2*A decrease in the probability of detection of corruption or in the marginal disutility of the sanction upon detected corruption induces an increase in the level of emissions or a reduction in the level of environmental regulation.*

Solving (11) for Δ^i, we obtain a function $\Delta_s^i(b^i)$ that can be interpreted as a supply function of emissions (or environmental regulation) which is an input of the firm in our model. In this context the agent's objective function becomes

$$\max_{\Delta_k^i} \psi_k^i \pi^i \left(y^1, y^2, \widetilde{z}^i + \Delta_k^i\right) - \phi\left(\widetilde{z}^i + \Delta_k^i\right) - b^i \Delta_k^i. \tag{12}$$

The constraint remains the same as in the model of the previous section. Maximization behavior of the agent and profit maximization of the firm imply

$$\psi_k^i \left[\pi_j^i \frac{\partial y^j}{\partial y^i} \frac{\partial y^i}{\partial z^i} - e_z^i\right] - \phi_z - b^i = 0. \tag{13}$$

The present framework implies that the level of corruption may be viewed as a public good for the shareholders of the firm. This gives the agent an incentive to free ride and wait for the other shareholders to finance the corrupt bureaucrat. Then, the level of corruption will be determined by the demand for emissions or polution (or lower regulations) of the *richest* agent

$$\psi_{\max}^i \left[\pi_j^i \frac{\partial y^j}{\partial y^i} \frac{\partial y^i}{\partial z^i} - e_z^i\right] - \phi_z - b^i = 0. \tag{14}$$

From (14), we obtain a function $\Delta_d^i\left(b^i : \psi_{\max}^i\right)$ that can be interpreted as a demand function for emissions (or lower regulation) which is increasing in $\psi_{\max}^i$. For simplicity, we assume that both the bureaucrat and the richest agent are price takers so that the level of emissions (or regulation) is determined by $\Delta_d^i\left(b^i : \psi_{\max}^i\right) = \Delta_s^i\left(b^i\right)$. It is important to note here that although the richest agent is a price taker on the national emissions (or regulation) market, he is still engaged in a strategic game with the richest agent of the rival country.

Proposition 3*In presence of corruption, the Nash equilibirum of the game* $(\widetilde{z}^1, \widetilde{z}^2, \widetilde{y}^1, \widetilde{y}^2)$ *is implicitely defined by (4), (11) and (14) for* $i = 1$ *and* 2.

In this model, the impact of wealth or income inequality is not clear. If an increase of inequality induces a reduction of the median voter share of the national firm, keeping the maximum share constant, the level of emissions decreases. However, if the increase in inequality increases the maximum share keeping the median share constant, the level of emissions increases. If a change in inequality modifies simultanously the median share and the maximum share, the impact on the level of emissions is unclear. In this context, we have two forces that work in opposite directions and the total impact is uncertain.

Proposition 4*If the environmental standard is fixed by a corrupt bureaucrat, than an increase in inequality in wealth distribution*

1. *induces higher emissions if the maximum share of the national firm owned by the richest individual increases and the median share is unchanged,*
2. *induces lower emissions if the median share decreases and the maximum share is unchanged,*
3. *has an ambiguous impact on the level of emissions if the median share decreases and the maximum share increases.*

5 Data and Empirical Analysis

In the previous section, we developed two models for the determination of environmental standard. The first model suggests that inequality will induce reinforcement in the level of environmental regulation, thus an improvement in pollution situation. However, in the presence of corruption, higher inequality facilitates lobbying activities, therefore the environmental regulation risks to be weakened; therefore, we should expect an increase in pollution. In order to test the predictions of our models, we use an unbalanced panel data on environmental pollution, corruption and inequality of over 80 countries during 1980-2005.

5.1 The data

Since the models directly established the impact of inequality and corruption on environmental standard, the best choice for the dependant variable should naturally be the measurement of environmental policy stringency. However, according to our knowledge, there currently exist only two cross-country data series. One is developed by Dasgupta, Mody, Roy and Wheeler (1995) and is based on the self-compiled reports by individual countries prior to the UN Earth Summit in Rio de Janeiro, Brazil, in 1992. This cross-country database, however, only covers 31 countries. Although Eliste and Fredriksson (2002) have tried to use the same methodology to compile the same index for another 31 countries, the total observation offered by this series is nevertheless limited to 62 points. Pellegrini (2006) used this database to test the relationship between corruption, democracy and environmental policy. However, since he is combining data from difference sources, his analysis is constrained to only 54 observations.

Another index qualifying the stringency of environmental policy is the environmental regulatory regime index compiled by Esty and Porter (2002), which is based on the environmental sustainability index and the Global Competitiveness Report 2001-2002 survey of business and government leaders[1]. Although Esty and Porter (2002) showed that the index is a statistically significant predictor of pollution level, it must be noted, however, that counties for which the environmental regulatory regime index is available tend to be more democratic than the world average. Furthermore, as the Dasgupta et al. (1995) data, this series also has only one observation for each country, therefore the dynamic aspects between inequality, corruption and environmental regulation is impossible to capture.

Considering the fact that the judgment on the quality of the subjective environmental regulation strictness index is often based on whether they can predict the actual pollution level in each country[2], we will estimate the regression models for a number of air pollution indicators obtained from various sources:

1. Per capita SO_2 emission data over 200 countries during the 1980-2002 period compiled by Stern (2005) based on the ASL database (prior to 1990), various sources of published sulfur data during 1990-2000 and the interpolation or extrapolation using either econometric models or simple extrapolation for the remaining countries and for missing years for countries with some published data[3]. More details about the data can be found in Stern (2005).

2. Per capita anthropogenic CO_2 emission data for over two hundred countries

[1] Porter, Sachs and Schwab (2002)

[2] Esty and Porter (2002)

[3] The database is available from Stern's personal page: http://www.rpi.edu/ sternd/datasite.html

for the period 1980-2002, estimated by Carbon Dioxide Information Analysis Center (CDIAC), based primarily on energy statistics collected by the United Nations and reported in the Statistical Yearbook (Marland et al., 2003; United Nations Statistics Division, 2004). We obtained this part of data from World Development Index (WDI, 2006).

3. Per capita nitrogen oxides (NO_x) originally compiled by Carbon Dioxide Information Analysis Center (CDIAC), Environmental Sciences Division, Oak Ridge National Laboratory, which is available in WDI (2006) and from World Resources Institute[4] for over 200 countries in 1990, 1995 and 2000. Nitrous oxide emissions are those stemming from agriculture, biomass burning, industrial activities, and livestock management.

For the independent variables, income inequality is proxied by the recently updated UNU/WIDER World Income Inequality Database v. 2.0a. Unlike national accounts data, which are in principle comparable across countries, there is no agreed basis of definition for distribution data. The advantage of the WIID2a database, which originates from different sources and refers to a variety of income and population concepts, sample sizes and statistical methods, is that it actually offers us a maximum number of choices for the distribution data for each country according to various conceptual bases[5]. Following on the principle to keep as many good quality data as possible and to preserve a good coherence in distribution conceptual basis, we choose the household-level disposable income concept for inequality measurement. This choice allows us to keep a relatively large $GINI$ coefficient panel data series for 119 countries over 1980-2003 with 878 observations.

The data on corruption perception is gathered by Transparency International[6]. The original corruption index reported in this series is a composite index which generally uses several different surveys of different sampling

[4] Through the website at: http://earthtrends.wri.org/

[5] The principal sources of the inequality data included in WIID2a are : Deininger and Squire (1997, 2004); the unit record data of the Luxembourg Income Study (LIS), the Transmonee data by UNICEF/ICDC, Central Statisitcal Offices and Research Studies. For more detailed information about the compilation of the data, please refer to the World Income Inequality Database User Guide, which is available along with the database at the website: http://www.wider.unu.edu/wiid/wiid.htm.

[6] www.transparency.org

frames and methodologies in the aim of giving statistically robust means of measuring perception of corruption[7]. It covers various aspects of corruption: the frequency of bribes paid, total value of bribes paid and the damage to private business people caused by corruption, etc. The original index is normalized and varies in the range of 0-10 with a bigger number meaning less corruption. We transformed the original index by subtracting it from 10, so that an increase in the index has an intuitive meaning of an increase in corruption. Transparency international has data from 1980 to 2005. Although at the beginning, there were only a relatively small number of countries having their index reported, since 1995, the coverage of the Transparency International expanded rapidly. In 2006, over 162 countries have their corruption perception index reported by this institution. Pelligrini (2006) found a stable relation between the indices reported in earlier periods and those from recent surveys and, therefore concluded that the indices from recent years can be used to complete the other set of indices, without further transformation.

Several other indicators widely accepted as the economics determinants of pollution are also used in our estimations. This include among others per capita income, population density and share of industrial value added in GDP, etc. We obtained these data from the World Development Indicator (WDI, 2006).

5.2 Methodology

As we choose to investigate how inequality and its co-existence with corruption affect final pollution result, it is difficult to avoid the literature of the Environmental Kuznets Curve hypothesis. As one of the most controversial topic in Environmental Economics studies, the EKC hypothesis assumes the relationship between environmental degradation indicators and per capita income to be depicted by an inverted U curve. We will employ in this paper

[7] The surveys used in the compilation of corruption perception index comes from the following institutions: Freedom House Nations in Transit (FH), the Economist Intelligence Unit (EIU), the Institute for Management Development, Lausanne (IMD), the International Crime Victim Survey (ICVS), Political Risk Services (PRS), the Political and Eonomic Risk Consultancy, Hong Kong (PERC), the World Bank and European Bank for Reconstruction and Development (WB), and the World Economic Forum (WEF).

the strategy called "augmented EKC model" to investigate how the situation of inequality and corruption in one country can affect the evolution of its air pollution indicator with economic growth originally suggested by EKC hypothesis[8].

For this purpose, we carry out the following three estimation steps for each air pollution indicator:
(1) traditional EKC model:

$$E_{it} = \gamma_i + \alpha_1 Y_{it} + \alpha_2 Y_{it}^2 + \alpha_3 Y_{it}^3 + \alpha_4 Z_{it} + \varepsilon_{it}, \tag{15}$$

(2) EKC model augmented by inequality situation

$$E_{it} = \gamma_i + \alpha_1 Y_{it} + \alpha_2 Y_{it}^2 + \alpha_3 Y_{it}^3 + \alpha_4 Z_{it} + \beta_1 GINI_{it} + \varepsilon_{it}, \tag{16}$$

(3) and EKC model augmented by inequality and corruption situation

$$E_{it} = \gamma_i + \alpha_1 Y_{it} + \alpha_2 Y_{it}^2 + \alpha_3 Y_{it}^3 + \alpha_4 Z_{it} + \beta_1 GINI_{it} + \beta_2 GINI_{it} \times corruption_{it} + \varepsilon_{it}, \tag{17}$$

where the subscripts i and t denote country and year, respectively. Equation (15) is the traditional EKC model, where the air pollution indicator (E_{it}) is a function of per capita income (Y_{it}) and other specific economic characteristics (Z_{it}). As in the traditional EKC studies, to obtain the potential curvature in the correlation between pollution and income growth, quadratic and cubic income terms are also included when necessary. In equation (16), this EKC model is augmented by the inclusion of inequality situation ($GINI_{it}$). According to our theoretical model, we expect a negative coefficient for $GINI_{it}$, which signifies reduction of pollution incidence when inequality situation is more serious. γ_i is included to capture the country-specific effect, which is technically feasible since we will work on a unbalanced panel data set of over 80 countries for several years.

Equation (17) further augments the traditional EKC model by including at the same time $GINI$ and its multiplicative term with corruption. According to our second theory, we should expect a negative value for β_1 but

[8] The similar strategy has also been used by Heerink et al. (2001) and Cole (2007).

a positive value for β_2, which indicates that the co-existence of a high level of inequality and corruption is bad for the environment.

As the terms $GINI$ and *corruption* have been included additively to the traditional EKC model, an implicit hypothesis of the EKC augmented model (2) and (3) is that the situation of the inequality and corruption of an individual country can only make the average EKC to move up- and down-wards. But it is possible that the inequality and corruption situation could directly affect the correlation between pollution and income growth by changing the curvature or form of the EKC. To investigate this possibility, we will also estimate the following two models:
(4) slope-augmented EKC model by inequality

$$E_{it} = \gamma_i + \alpha_1 Y_{it} + \alpha_2 Y_{it}^2 + \alpha_3 Y_{it}^3 + \alpha_4 Z_{it} + \delta_1 \left(GINI_i \times Y_{it} \right) + \varepsilon_{it}, \tag{18}$$

(5) slope-augmented EKC model by inequality and corruption

$$E_{it} = \gamma_i + \alpha_1 Y_{it} + \alpha_2 Y_{it}^2 + \alpha_3 Y_{it}^3 + \alpha_4 Z_{it} + \delta_1 \left(GINI_i \times Y_{it} \right) + \delta_2 \left(GINI_i \times corruption_{it} \times Y_{it} \right) + \varepsilon_{it}. \tag{19}$$

Here the mechanism used to check the changes in curvature of EKC is the multiplicative terms of per capita income Y_{it} with $GINI_{it}$ and $corruption_{it}$. If our model predicts correctly, we should expect a negative value for δ_1 but a positive value for δ_2.

5.3 Results

Table 1-3 present the fixed effect estimation results for the four pollution indicators. The columns titled (1)-(5) report the estimation results directly based on the five EKC models proposed above. Two variations in Model (3) and (5) are also reported in the same table for comparison[9].

In accordance to the EKC literature, we find a significant inverted-U-form correlation between per capita income and per capita SO_2 and NO_x

[9] In order to test the model sensitivity to the choice of functional form, we also regress the four pollution indicators on logarithm per capita income. The estimation results are given in the appendix B. As can be seen, our general conclusion is fairly robust to such changes. Appendix A reports the summary statistics.

emissions with the turning point situating around 13000 USD and 15000 USD (2000 constant price), respectively[10]. As a global pollution case, we find an increasing trend for per capita CO_2 emission, as most of the similar studies[11]. The estimated coefficients associated to population density and industrial GDP share also have the expected signs.

The inclusion of the variable $GINI$ into the traditional EKC model, through linear participation in Model (2) or multiplied with per capita income in Model (4), does not affect the stability of the traditional EKC. For all three emission cases, we obtain the expected significant negative coefficients for the $GINI$-related terms in Model (2), although the coefficient estimated for the NO_x pollution case is not statistically significant. This result confirms the expected role of $GINI$ discussed in our first theoretical model. The $GINI$-related term in the slope-augmented EKC model (4) also gives the expected negative coefficients, but most of these coefficients are not statistically significant. We thus suspect that the expected environment-friendly role of $GINI$ may function more in an average way, independent of country income level.

The inclusion of the multiplicative term between $GINI$ and corruption index in Model (3) aims to test the prediction of our second theoretical model. The positive coefficients obtained for this term in all three emission cases confirm, in certain sense, our prediction that co-existence of inequality and corruption will reduce the quality of environmental regulation. However their unsatisfactory significance motivates us to deepen our investigation. A closer examination of the details of the corruption index reveals the fact that, during the period 1980-2002, countries originally having a relatively low corruption history generally have low values of corruption index all the time (e.g. most of the northern European countries), while those with long

[10]Empirical findings on EKC hypothesis based on international per capita SO2 emission generally predict the improvement to happen after per capita income attains the range of 4000-8000 USD (1985 price, PPP, Grossman and Krueger, 1995, Selden and Song, 1994 and Shafik, 1994, etc.), which is around 6400-12800 USD (2000 constant price). Egli (2002), Cole (2003), Cole et al. (1997), Cole (2004), Khanna (2002), Selden and Song (1994) general found higher turning point for per capita NOx emission compared to SO2.

[11]Cole et al. (1997), Cole (2004), Roca et al. (2001), York et al. (2003), Heil and Selden (2001). Ausuategi and Escapa, (2002), Holtz-Eakin and Selden (1995) and Egli (2002).

and heavy corruption history on the other hand always have high values for this index. Only the countries situated in the middle of these two cases experienced some obvious index changes. We therefore believe it would be more reasonnable to use this index as a cross-country comparison instead of as a dynamic description for changes in the situation of corruption in a specific country through time. We therefore decided to classify the countries into groups of different level of corruption.

In order to find a convincing classification standard, we reestimated Model (3), but this time, the corruption index in the multiplicative terms with $GINI$ are polynomial, with the corruption index appearing in both level, quadratic and cubic forms (c.f. column 3.1). Except for CO_2, the estimation results from all three pollution indicators show statistically significant coefficients and indicate that the relationship between pollution and $GINI$ does depend on the actual value of the corruption index. It is easy to deduce from the estimation results that the changes in the correlation between pollution and $GINI$ generally happens when the corruption level is around 3 and 7[12][13]. We therefore re-organise the countries into the three groups: low corruption countries (corruption index [0,3]), mean corruption countries (corruption index (3, 7]) and high corruption countries (corruption index (7, 10]). Model (3) is then re-estimated through a spline function, in which the coefficients of $GINI$ are distinguished between the groups of low, mean and high corruption level (c.f. column 3.2)[14]. As $GINI$ is multiplied in this model by three dummies that indicate whether or not a country belongs to low-, mean- or high-corruption group, single $GINI$ term can not be included at the same time.

We obtain more interesting results from this modified Model (3.2). In the per capita SO_2 emission case, the negative coefficients of the multiplicative terms is -514 for low corruption countries, -457 for mean corruption ones

[12]The estimation function arrangement is inspired by Antweiler et al. (2001).

[13]The reason for us to find two cuts to distinguish the countries into three corruption groups may be due to the generally found duo-peak (at 1.5 and 7.5 respectively) distribution density of corruption levels for the countries include into the estimation for all the four pollution cases. (c.f. Appendix C)

[14]The original multiplicative term between $GINI$ and corruption becomes the multiplication between $GINI$ and the three dummy variables that indicate the low, mean and high corruption countries.

and finally to -383 for high corruption ones. This actually confirms our theoretical prediction of a higher pollution reduction impact of $GINI$ for the countries having lower corruption degree. The same pattern of coefficients is also observed for the case of CO_2 (significant, but the difference between groups are much smaller) and NO_x emission (insignificant).

Corresponding results from Model (3.2) for all three pollution cases are also illustrated graphically in Figure 1-3. For reference, we depicted firstly the simple EKC (the thick solid line) purged of the height-adjustment effect from $GINI$ and corruption index in all the panels. Then, we use the three different values of $GINI$: Low (15th percentile value of the sample), Mean (50th percentile value of the sample) and High (85th percentile value of the sample) to illustrate separately the height reduction impact of $GINI$ on EKC. Comparison between the three panels on the top part of figure 1-3 shows that the height-reduction effect of $GINI$ on EKC increases with the $GINI$ index. In each panel, we also indicate the height-adjusted EKC caused by the same inequality level for the three different country groups that have low, mean and high corruption level. The three panels of the per capita SO_2 emission case reveal the most obvious between-group differences. Such a difference is also visible in the NO_x case. On the other hand, group differences in the CO_2 case are too small to be seen graphically. This can be explained by the fact that CO_2 is a global pollution, the trade-off between the negative damage suffered by people and the benefit obtained by the polluter is thus much more difficult to capture than in the local pollution cases of SO_2 or NO_x. Confirming our theoretical prediction, in all of the three cases, the height-adjusted EKCs (illustrated by the thin solid lines) of the country group having the lowest corruption level are situated at the lowest position. A little higher is the corresponding EKC for mean-corruption group (c.f. the long dashed line) and finally, just below the thick simple EKC, is the height-adjusted EKC for high corruption group (the short dashed line).

The results for Model (5) reveal similar conclusions as Model (3). Though a positive coefficient is found for the multiplicative term ($GINI \times corruption \times gdppc$), which is now constructed to change the EKC curvature for three out of four pollution cases (SO_2, CO_2 and NO_x), they all suffer from weak significance. We therefore employ the same strategy as in Model (3) that is we try to determine the role of corruption by classifying the countries into groups according to the level of their corruption. Model (5.1) therefore estimates the slope-augmented EKC model with multiplicative terms including the polynomial corruption index. Once more, the results reveal that countries should be classified into three groups with the cutting points situated at $corruption = 2$ and $corruption = 6$ for all four pollution cases. Based on this classification principle, in Model (5.2), we re-arrange the multiplicative EKC-slope-modifying terms into $(GINI \times corruption_{low} \times gdppc)$, $(GINI \times corruption_{mean} \times gdppc)$, $(GINI \times corruption_{high} \times gdppc)$, where $corruption_{low}$, $corruption_{mean}$ and $corruption_{high}$ are the three dummies indicating that a country belongs to a specific corruption level group. Although the statistically significance of these multiplicative terms is generally weaker when compared to their counter-parts in height-augmented EKC models, their value (for the SO_2 and CO_2 cases) do confirm our prediction[15]. Indeed, we obtain a decreasing tendency in the absolute value of the negative coefficients for the three terms $(GINI \times corruption_{low} \times gdppc)$, $(GINI \times corruption_{mean} \times gdppc)$ and $(GINI \times corruption_{high} \times gdppc)$, which reveals a weakening of the slope-reduction impact of $GINI$ in EKC curve with the increase of corruption index.

Figure 1-3 provides a graphical illustration for the results of Model (5.2). Once more, the most obvious effects of $GINI$ and $corruption$ on EKC is found in the SO_2 case. The assumption that the inequality and corruption situation of a country can affect the curvature of EKC is only confirmed for SO_2 and CO_2 pollution cases. The three panels on the bottom of Figures 1 and 2 illustrate the two predictions of our theoretical models: firstly, an increase of the $GINI$ index leads to a decrease of the pollution level for a given per capita income level. In addition, this pollution reduction impact is reinforced by income growth. Secondly, the countries with the lowest corruption level enjoy the most height and curvature reduction of EKC brought by income inequality, although the degradation of the corruption situation weakens this environment-friendly impact. The higher the income inequal-

[15]The unsatisfactory significance of slope-augmented EKC model can find its origines from Model (4), where the $GINI \times gdppc$ has already given relatively weak significant coefficient.

ity, the more important this weakening effect is.

6 Conclusion

In this paper, we have proposed two public choice models to analyze the impact of corruption and inequality on environmental regulation. In the absence of corruption, regulation is determined by a majority vote, and higher inequality leads to better environmental standards. With corruption, the environmental standard is chosen by a corrupt bureaucrat. In this case, a higher level of corruption should reduce the quality of environmental regulation.

These two theoretical models were then tested using a cross-country panel data set, in order to capture the potential adjustment in both height and curvature of the average EKC that can be caused by income inequality and the corruption situation of each country. The prediction of both models are confirmed for per capita SO_2 and CO_2 emissions, although the latter, as a global pollution case, shows smaller adjustment effects. The per capita NO_x emission only confirms the height adjustment of EKC but not the curvature transformation. Generally we believe our empirical analysis confirms our theoretical models.

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Table 1. Per capita SO_2 emission (g/person)-Fixed effect

	(1)	(2)	(3)	(3.1)	(3.2)	(4)	(5)	(5.1)	(5.2)
Gdppc	8.214	8.841	8.833	9.146	9.386	8.452	8.317	8.444	8.690
	(2.15)**	(2.29)**	(2.27)**	(2.34)**	(2.20)**	(2.29)**	(2.19)**	(2.21)**	(2.22)**
$gdppc^2$ (1/10000)	-4.292	-4.567	-4.560	-4.626	-4.788	-4.331	-4.255	-4.120	-4.437
	(2.64)***	(2.80)***	(2.77)***	(2.83)***	(2.68)***	(2.70)***	(2.59)***	(2.52)**	(2.58)**
$gdppc^3$(1/100000000)	0.606	0.648	0.647	0.649	0.677	0.615	0.604	0.569	0.632
	(2.73)***	(2.92)***	(2.88)***	(2.95)***	(2.80)***	(2.86)***	(2.76)***	(2.62)***	(2.73)***
industryp	702.203	629.488	631.845	636.870	644.630	691.505	704.803	699.746	704.704
	(4.07)***	(3.80)***	(3.72)***	(3.66)***	(3.84)***	(3.84)***	(3.78)***	(3.81)***	(3.71)***
Popden	-12.711	-9.295	-9.181	-8.478	-9.318	-12.028	-11.954	-13.476	-11.265
	(4.77)***	(3.10)***	(2.90)***	(1.98)**	(3.10)***	(4.45)***	(4.29)***	(3.91)***	(3.71)***
Gini		-442.779	-461.499	-465.840					
		(3.03)***	(2.75)***	(2.39)**					
gini×corruption			3.874	136.516					
			(0.20)	(1.55)°					
$gini×corruption^2$				-33.961					
				(1.72)*					
$gini×corruption^3$				2.293					
				(1.90)*					
gini×corrupt_low					-514.062				
					(2.67)***				
gini×corrupt_mean					-457.100				
					(3.12)***				
gini×corrupt_high					-383.407				
					(2.59)***				
gini×gdppc						-0.005	-0.008	-0.017	
						(0.61)	(0.88)	(1.99)**	
gini×corruption×gdppc							0.001	0.019	
							(0.68)	(3.96)***	
$gini×corruption^2×gdppc$								-0.007	
								(3.50)***	
$gini×corruption^3×gdppc$								0.001	
								(2.94)***	
gini×corrupt_low×gdppc									-0.010
									(1.18)
gini×corrupt_mean×gdppc									-0.007
									(0.79)
gini×corrupt_high×gdppc									-0.005
									(0.43)
R-squared	0.24	0.25	0.25	0.26	0.26	0.24	0.24	0.27	0.24
F test	56.66	32.96	27.73	16.56	24.88	49.05	40.83	24.78	39.39
Breuch-Pagan	3192.15 (0.000)	2985.63 (0.000)	1904.01 (0.000)	1640.03 (0.000)	2280.69 (0.000)	2763.95 (0.000)	2538.66 (0.000(	2292.47 (0.000)	2421.10 (0.000)
Hausman	7.55 (0.1826)	11.96 (0.0628)	32.73 (0.000)	30.11 (0.0004)	36.92 (0.000)	10.70 (0.0980)	16.80 (0.01807)	23.35 (0.0006)	22.42 (0.0042)
Observations	436	436	436	436	436	436	436	436	436
Number of country	79	79	79	79	79	79	79	79	79

- Robust t statistics in parentheses, ° significant at 15%, * significant 10%, ** significant 5%, *** significant 1%.

Table 2. Per capita CO_2 emission (kg/person)-Fixed effect

	(1)	(2)	(3)	(3.1)	(3.2)	(4)	(5)	(5.1)	(5.2)
Gdppc	0.926	0.955	0.955	0.974	0.958	0.943	0.915	0.946	0.968
	(6.58)***	(6.80)***	(6.77)***	(6.96)***	(6.43)***	(6.11)***	(5.73)***	(6.06)***	(6.41)***
$gdppc^2$ (1/10000)	-0.331	-0.341	-0.340	-0.342	-0.342	-0.332	-0.317	-0.319	-0.342
	(4.49)***	(4.69)***	(4.67)***	(4.74)***	(4.60)***	(4.49)***	(4.20)***	(4.34)***	(4.65)***
$gdppc^3$(1/100000000)	0.043	0.045	0.044	0.044	0.045	0.044	0.041	0.041	0.045
	(3.46)***	(3.63)***	(3.61)***	(3.62)***	(3.61)***	(3.49)***	(3.27)***	(3.31)***	(3.62)***
industryp	37.174	31.822	32.033	32.274	31.987	36.258	38.068	37.961	37.078
	(3.04)***	(2.67)***	(2.66)***	(2.64)***	(2.67)***	(2.93)***	(3.03)***	(3.02)***	(2.91)***
Popden	0.027	0.244	0.254	0.223	0.244	0.076	0.079	-0.003	0.164
	(0.02)	(0.17)	(0.18)	(0.16)	(0.17)	(0.05)	(0.05)	(0.00)	(0.11)
Gini		-28.914	-30.716	-39.490					
		(2.05)**	(1.99)**	(2.04)**					
gini×corruption			0.416	11.616					
			(0.41)	(1.32)					
gini×$corruption^2$				-2.311					
				(1.42)					
gini×$corruption^3$				0.136					
				(1.50)					
gini×corrupt_low					-28.970				
					(1.90)*				
gini×corrupt_mean					-29.509				
					(2.11)**				
gini×corrupt_high					-27.712				
					(1.99)**				
gini×gdppc						-0.0004	-0.001	-0.002	
						(0.36)	(0.73)	(1.42)	
gini×corruption×gdppc							0.0008	0.001	
							(1.34)	(2.86)***	
gini×$corruption^2$×gdppc								-0.0004	
								(2.69)***	
gini×$corruption^3$×gdppc								0.00003	
								(2.43)**	
gini×corrupt_low×gdppc									-0.001
									(0.79)
gini×corrupt_mean×gdppc									-0.0005
									(0.41)
gini×corrupt_high×gdppc									-0.0003
									(0.27)
R-squared	0.23	0.23	0.23	0.24	0.23	0.23	0.23	0.25	0.23
F test	12.89	11.01	9.39	8.33	9.93	11.60	10.64	8.87	11.00
Breuch-Pagan	3097.76 (0.000)	3212.70 (0.000)	3167.95 (0.000)	3134.47 (0.000)	2618.80 (0.000)	2324.34 (0.000)	2274.55 (0.000)	2098.45 (0.000)	2274.43 (0.000)
Hausman	6.26 (0.2821)	10.39 (0.1093)	10.03 (0.1870)	15.17 (0.0863)	24.58 (0.0018)	22.75 (0.0009)	40.24 (0.000)	11.56 (0.2390)	17.19 (0.0213)
Observations	472	472	472	472	472	472	472	472	472
Number of country	83	83	83	83	83	83	83	83	83

- Robust t statistics in parentheses, ° significant at 15%, * significant 10%, ** significant 5%, *** significant 1%.

Table 3. Per capita NOx emission (kg/person)-Fixed effect

	(1)	**(2)**	**(3)**	**(3.1)**	**(3.2)**	**(4)**	**(5)**	**(5.1)**	**(5.2)**
Gdppc	0.228	0.234	0.242	0.193	0.248	0.246	0.244	0.176	0.264
	(1.73)*	(1.81)*	(1.75)*	(1.58)°	(1.41)	(1.83)*	(1.82)*	(1.19)	(1.88)*
gdppc^2 (1/10000)	-0.100	-0.105	-0.107	-0.084	-0.110	-0.105	-0.105	-0.079	-0.108
	(1.91)*	(2.04)**	(1.97)*	(1.81)*	(1.58)°	(1.98)*	(1.96)*	(1.34)	(1.99)*
gdppc^3(1/100000000)	0.013	0.014	0.014	0.011	0.014	0.014	0.014	0.010	0.014
	(1.92)*	(2.11)**	(2.05)**	(1.87)*	(1.64)*	(2.02)**	(2.01)*	(1.28)	(2.04)**
industryp	14.049	12.462	13.041	15.429	12.547	13.055	13.234	14.759	12.770
	(2.02)**	(1.59)°	(1.58)°	(1.70)*	(1.51)	(1.78)*	(1.77)*	(2.11)**	(1.72)*
Popden	0.047	0.089	0.082	-0.054	0.092	0.129	0.120	-0.092	0.143
	(0.75)	(0.99)	(0.89)	(0.41)	(1.03)	(0.84)	(0.78)	(0.60)	(0.94)
Gini		-5.825	-6.066	-2.112					
		(0.88)	(0.89)	(0.22)					
gini×corruption			0.197	7.771					
			(0.45)	(2.48)**					
gini×corruption^2				-1.748					
				(2.64)**					
gini×corruption^3				0.108					
				(2.62)**					
gini×corrupt_low					-6.438				
					(0.96)				
gini×corrupt_mean					-5.697				
					(0.80)				
gini×corrupt_high					-5.654				
					(0.75)				
gini×gdppc						-0.0004	-0.0004	-9.26×10^{-7}	
						(0.63)	(0.60)	(0.00)	
gini×corruption×gdppc							0.00001	0.0004	
							(0.25)	(3.18)***	
gini×corruption^2×gdppc								-0.0001	
								(2.91)***	
gini×corruption^3×gdppc								0.00001	
								(2.64)**	
gini×corrupt_low×gdppc									-0.0006
									(0.90)
gini×corrupt_mean×gdppc									-0.0007
									(1.01)
gini×corrupt_high×gdppc									-0.0009
									(1.16)
R-squared	0.24	0.25	0.25	0.32	0.25	0.25	0.25	0.31	0.26
F test	2.87	2.65	2.35	3.56	2.11	2.20	1.97	6.36	2.10
Breuch-Pagan	35.25 (0.000)	35.70 (0.000)	36.79 (0.000)	33.17 (0.000)	35.99 (0.000)	35.87 (0.000)	33.38 (0.000)	30.56 (0.000)	35.25 (0.000)
Hausman	3.75 (0.5854)	4.64 (0.5913)	6.46 (0.4871)	3.65 (0.9331)	6.13 (0.6322)	5.12 (0.5286)	11.14 (0.1217)	10.24 (0.3317)	9.05 (0.3380)
Observations	77	77	77	77	77	77	77	77	77
Number of country	32	32	32	32	32	32	32	32	32

- Robust t statistics in parentheses, ° significant at 15%, * significant 10%, ** significant 5%, *** significant 1%.

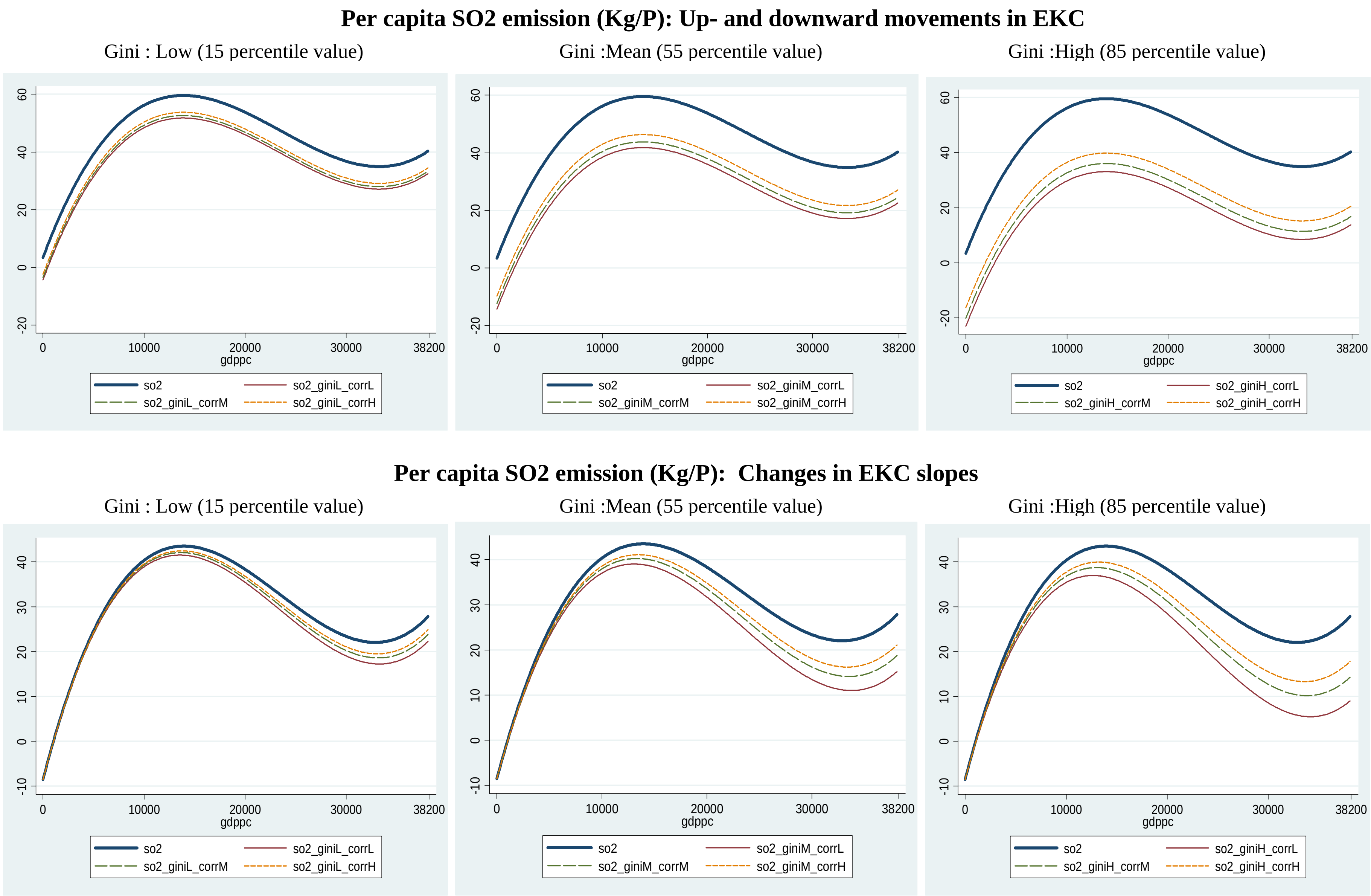


Figure 1. Augmented EKC model for per capita SO_2 emission

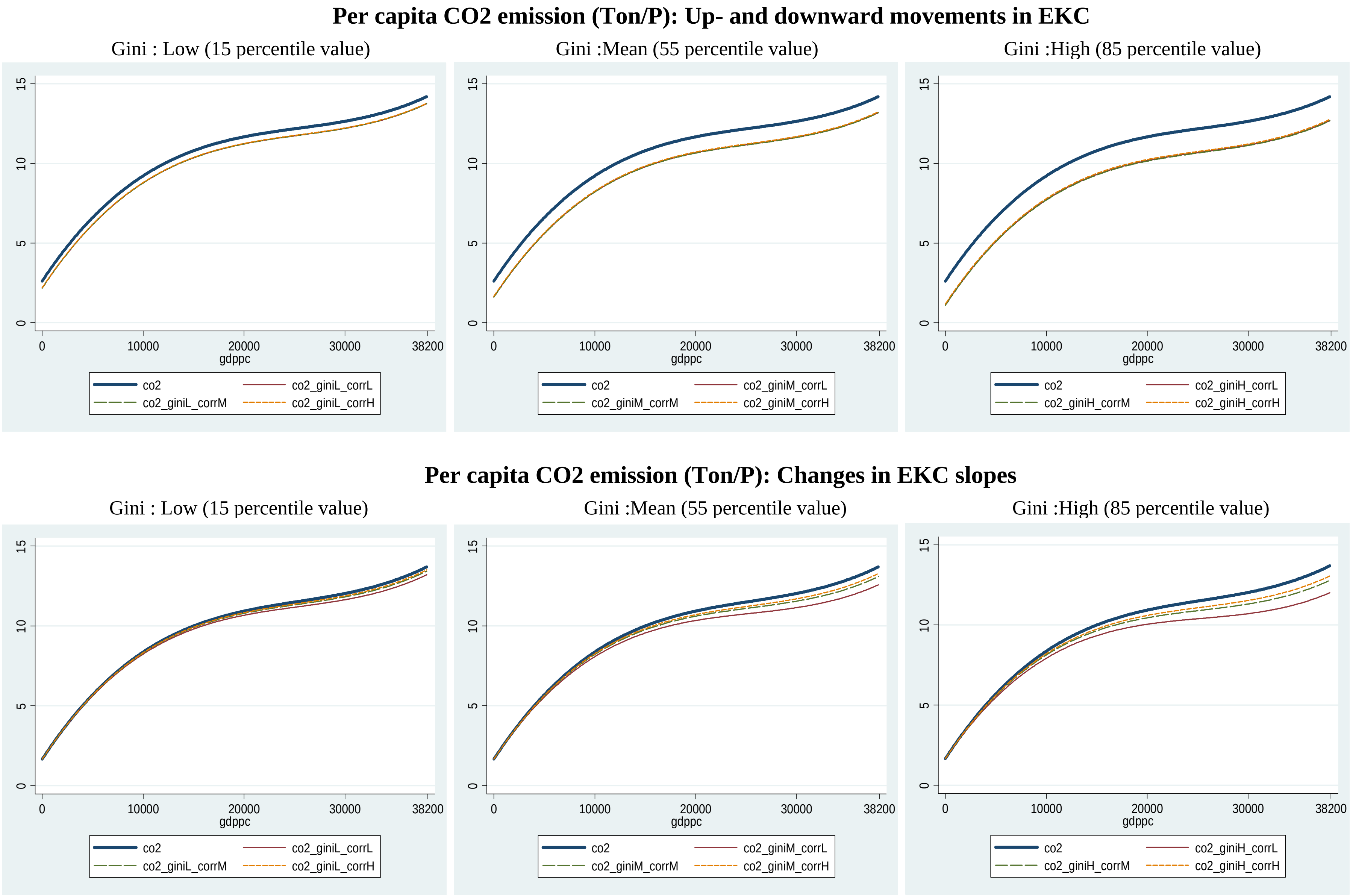
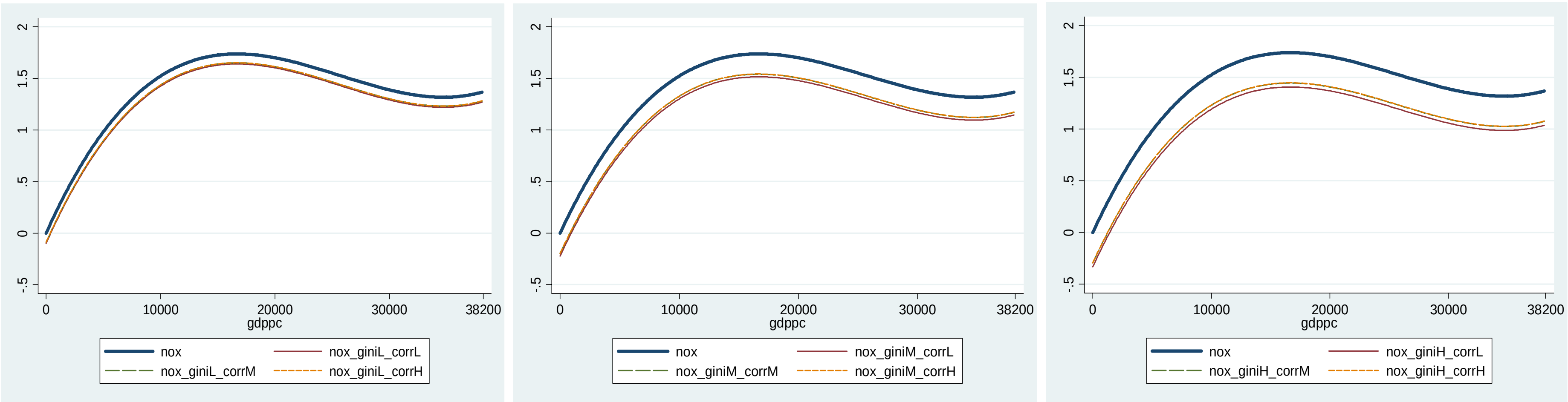


Figure 2. Augmented EKC model for per capita CO_2 emission

Per capita NOx emission (Ton/P) : Up- and downward movements in EKC

Gini : Low (15 percentile value) | Gini :Mean (55 percentile value) | Gini :High (85 percentile value)



Per capita NOx emission (Ton/g): Changes in EKC slopes

Gini : Low (15 percentile value) | Gini :Mean (55 percentile value) | Gini :High (85 percentile value)

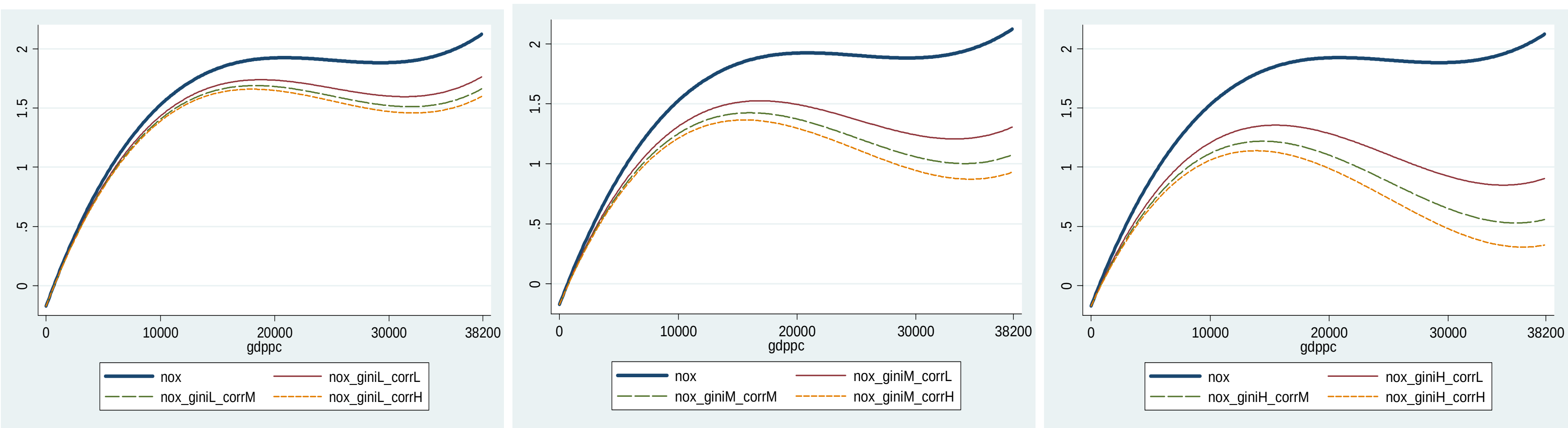


Figure 3. Augmented EKC model for per capita NOx emission

Appendix A. Summary Statistics (Estimation specified)

Variable	Units	Obs	Mean	Std. Dev.	Min	Max
SO_2 estimation						
SO_2	Per capita SO_2 emission, tons/p	436	0.019	0.021	0.0005	0.141
gdppc	Per capita GDP, constant USD year 2000	436	11365.2	10538.99	101.5248	38200.41
gini	Gini index	436	37.686	10.754	17.4	66.6
corruption	Corruption Index, 0-100	436	4.434	2.629	0.000	10.000
popden	Population density, person/km^2	436	161.925	612.813	1.943	5996.567
industryp	Percentage of industrial GDP,%	436	32.803	6.603	9.444	58.256
CO_2 estimation		**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
CO_2	Per capita CO_2 emission, tons/p	472	6.905	5.021	0.045	20.657
gdppc	Per capita GDP, constant USD year 2000	472	11309.500	10399.080	101.525	38200.410
gini	Gini index	472	37.530	10.575	17.400	66.600
corruption	Corruption Index, 0-100	472	4.412	2.630	0.000	10.000
popden	Population density, person/km^2	472	162.293	589.423	1.943	5996.567
industryp	Percentage of industrial GDP,%	472	32.835	6.639	9.444	58.256
NOx estimation		**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
NO_x	Per capita NOx emission, tons/p	77	0.998	0.570	0.213	2.693
	Per capita GDP, constant USD year 2000	77	13954.53	10063.13	391.655	37164.6
gini	Gini index	77	37.229	10.817	20.100	63.300
corruption	Corruption Index, 0-100	77	3.902	2.713	0.000	9.580
popden	Population density, person/km^2	77	239.510	894.174	2.221	5996.567
industryp	Percentage of industrial GDP,%	77	33.163	6.111	22.822	50.110

Appendix B. Estimation results based on semi-log function

Table B1. Per capita SO_2 emission (kg/person)-Fixed effect

	(1)	**(2)**	**(3)**	**(3.1)**	**(3.2)**	**(4)**	**(5)**	**(5.1)**	**(5.2)**
Ln(gdppc)	-552.049	-510.997	-516.942	-503.291	-572.678	-527.824	-532.023	-517.439	-538.877
	(3.10)***	(2.89)***	(2.95)***	(3.01)***	(2.88)***	(2.95)***	(3.00)***	(3.08)***	(2.95)***
$Ln(gdppc)^2$	73.440	68.787	69.464	68.105	76.507	70.848	71.290	69.809	72.043
	(3.20)***	(3.02)***	(3.07)***	(3.13)***	(3.00)***	(3.07)***	(3.11)***	(3.20)***	(3.05)***
$Ln(gdppc)^3$	-3.136	-2.957	-2.982	-2.935	-3.264	-3.033	-3.047	-2.996	-3.076
	(3.35)***	(3.18)***	(3.23)***	(3.30)***	(3.16)***	(3.23)***	(3.26)***	(3.36)***	(3.18)***
industryp	0.747	0.664	0.674	0.656	0.699	0.683	0.693	0.672	0.711
	(4.21)***	(3.77)***	(3.70)***	(3.51)***	(3.85)***	(3.80)***	(3.70)***	(3.53)***	(3.76)***
Popden	-0.011	-0.010	-0.009	-0.009	-0.009	-0.010	-0.010	-0.009	-0.009
	(3.16)***	(2.58)**	(2.20)**	(1.49)	(2.26)**	(2.65)***	(2.37)**	(1.46)	(2.35)**
Gini		-0.406	-0.452	-0.488					
		(2.51)**	(2.57)**	(2.41)**					
gini×corruption			0.011	0.154					
			(0.56)	(1.59)°					
$gini×corruption^2$				-0.037					
				(1.75)*					
$gini×corruption^3$				0.002					
				(1.93)*					
gini×corrupt_low					-0.463				
					(2.39)**				
gini×corrupt_mean					-0.408				
					(2.52)**				
gini×corrupt_high					-0.304				
					(1.81)*				
gini×ln(gdppc)						-0.040	-0.045	-0.049	
						(2.04)**	(2.10)**	(2.23)**	
gini×corruption×ln(gdppc)							0.001	0.022	
							(0.45)	(2.17)**	
$gini×corruption^2×$ ln(gdppc)								-0.006	
								(2.41)**	
$gini×corruption^3×$ ln(gdppc)								0.0004	
								(2.62)***	
gini×corrupt_low× ln(gdppc)									-0.048
									(2.42)**
gini×corrupt_mean× ln(gdppc)									-0.045
									(2.16)**
gini×corrupt_high× ln(gdppc)									-0.037
									(1.79)*
R-squared	0.24	0.25	0.25	0.26	0.26	0.24	0.24	0.26	0.25
F test	16.44	16.33	13.69	11.70	13.11	17.75	15.25	13.05	30.55
Breuch-Pagan	3105.53	2984.51	1925.83	1641.95	2290.51	2947.37	1926.94	1651.58	2214.72
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Hausman	10.00	13.49	33.30	30.56	37.63	12.19	31.48	27.91	22.22
	(0.0752)	(0.0359)	(0.000)	(0.0004)	(0.0000)	(0.0578)	(0.0001)	(0.0007)	(0.0045)
Observations	436	436	436	436	436	436	436	436	436
Number of country	79	79	79	79	79	79	79	79	79

- Robust t statistics in parentheses, ° significant at 15%, * significant 10%, ** significant 5%, *** significant 1%.

Table B2. Per capita CO_2 emission (ton/person)-Fixed effect

	(1)	(2)	(3)	(3.1)	(3.2)	(4)	(5)	(5.1)	(5.2)
Ln(gdppc)	-3.208	-2.898	-2.967	-2.826	-2.911	-2.988	-3.096	-2.957	-3.100
	(2.33)**	(2.10)**	(2.14)**	(2.05)**	(2.08)**	(2.18)**	(2.24)**	(2.17)**	(2.11)**
$Ln(gdppc)^2$	0.319	0.311	0.316	0.312	0.311	0.326	0.333	0.328	0.331
	(3.37)***	(3.30)***	(3.33)***	(3.29)***	(3.25)***	(3.47)***	(3.50)***	(3.48)***	(3.25)***
industryp	0.036	0.029	0.029	0.029	0.029	0.030	0.030	0.029	0.031
	(2.78)***	(2.18)**	(2.19)**	(2.10)**	(2.19)**	(2.19)**	(2.19)**	(2.12)**	(2.24)**
Gini		-0.035	-0.037	-0.047					
		(2.32)**	(2.32)**	(2.40)**					
gini×corruption			0.001	0.013					
			(0.64)	(1.43)					
$gini\times corruption^2$				-0.003					
				(1.57)°					
$gini\times corruption^3$				0.000					
				(1.69)*					
gini×corrupt_low					-0.033				
					(2.03)**				
gini×corrupt_mean					-0.036				
					(2.38)**				
gini×corrupt_high					-0.034				
					(2.26)**				
gini×ln(gdppc)						-0.004	-0.004	-0.005	
						(1.98)**	(2.03)**	(2.28)**	
gini×corruption×ln(gdppc)							0.00008	0.002	
							(0.65)	(1.67)*	
$gini\times corruption^2\times ln(gdppc)$								-0.0003	
								(1.92)*	
$gini\times corruption^3\times ln(gdppc)$								0.00002	
								(2.12)**	
gini×corrupt_low× ln(gdppc)									-0.005
									(2.16)**
gini×corrupt_mean× ln(gdppc)									-0.004
									(1.97)**
gini×corrupt_high× ln(gdppc)									-0.004
									(1.76)*
R-squared	0.21	0.22	0.22	0.23	0.22	0.22	0.22	0.23	0.22
F test	22.84	18.93	15.10	12.64	14.29	18.53	14.73	12.60	23.34
Breuch-Pagan	3043.44 (0.000)	3191.50 (0.000)	3193.97 (0.000)	3174.97 (0.000)	2595.28 (0.000)	3150.70 (0.000)	3157.23 (0.000)	3054.61 (0.000)	3273.57 (0.000)
Hausman	3.35 (0.3406)	3.54 (0.4714)	9.04 (0.1074)	15.75 (0.0276)	82.80 (0.000)	3.51 (0.4765)	13.30 (0.0207)	17.66 (0.0136)	14.47 (0.0248)
Observations	472	472	472	472	472	472	472	472	472
Number of country	83	83	83	83	83	83	83	83	83

- Robust t statistics in parentheses, ° significant at 15%, * significant 10%, ** significant 5%, *** significant 1%.

Table B3. Per capita NOx emission (ton/person)-Fixed effect

	(1)	(2)	(3)	(3.1)	(3.2)	(4)	(5)	(5.1)	(5.2)
Ln(gdppc)	-15.062	-15.130	-16.751	-10.125	-15.287	-15.111	-16.008	-9.959	-15.610
	(1.59)°	(1.58)°	(1.46)	(0.96)	(1.18)	(1.58) °	(1.46)	(0.96)	(1.50)°
Ln(gdppc)^2	1.953	1.966	2.164	1.336	1.986	1.968	2.076	1.304	2.028
	(1.62)*	(1.62)*	(1.50)°	(1.01)	(1.21)	(1.62)*	(1.50)	(1.00)	(1.54)°
Ln(gdppc)^3	-0.081	-0.082	-0.090	-0.056	-0.083	-0.082	-0.086	-0.055	-0.084
	(1.67)*	(1.66)*	(1.54)°	(1.05)	(1.25)	(1.67)*	(1.54)°	(1.05)	(1.58)°
industryp	0.015	0.013	0.015	0.015	0.013	0.013	0.014	0.015	0.013
	(1.69)*	(1.41)	(1.34)	(1.32)	(1.29)	(1.43)	(1.34)	(1.40)	(1.37)
Popden	0.000	0.000	0.000	-0.000	0.000	0.000	0.000	-0.000	0.000
	(0.13)	(0.51)	(0.29)	(0.72)	(0.45)	(0.62)	(0.46)	(0.87)	(0.38)
Gini		-0.006	-0.007	-0.002					
		(1.03)	(1.09)	(0.27)					
gini×corruption			0.000	0.008					
			(0.62)	(2.68)**					
gini×corruption^2				-0.002					
				(3.05)***					
gini×corruption^3				0.000					
				(3.09)***					
gini×corrupt_low					-0.006				
					(0.92)				
gini×corrupt_mean					-0.006				
					(0.92)				
gini×corrupt_high					-0.006				
					(0.75)				
gini×ln(gdppc)						-0.001	-0.0009	-0.000	
						(1.08)	(1.09)	(0.08)	
gini×corruption×ln(gdppc)							0.00003	0.001	
							(0.42)	(2.92)***	
gini×corruption^2× ln(gdppc)								-0.000	
								(3.31)***	
gini×corruption^3× ln(gdppc)								0.000	
								(3.30)***	
gini×corrupt_low× ln(gdppc)									-0.001
									(1.30)
gini×corrupt_mean× ln(gdppc)									-0.002
									(1.88)*
gini×corrupt_high× ln(gdppc)									-0.002
									(1.91)*
R-squared	0.18	0.19	0.20	0.28	0.19	0.20	0.20	0.29	0.22
F test	1.63	1.78	1.58	2.79	1.50	1.68	1.58	3.41	3.27
Breuch-Pagan	34.25 (0.000)	35.31 (0.000)	35.82 (0.000)	31.32 (0.000)	35.84 (0.000)	35.32 (0.000)	35.88 (0.000)	31.41 (0.000)	35.50 (0.000)
Hausman	4.26 (0.5211)	5.65 (0.4638)	7.22 (0.4065)	5.32 (0.8054)	7322 (0.4065)	6.29 (0.6146)	7.73 (0.3572)	5.21 (0.8151)	6.39 (0.4060)
Observations	77	77	77	77	77	77	77	77	77
Number of country	32	32	32	32	32	32	32	32	32

- Robust t statistics in parentheses, ° significant at 15%, * significant 10%, ** significant 5%, *** significant 1%.

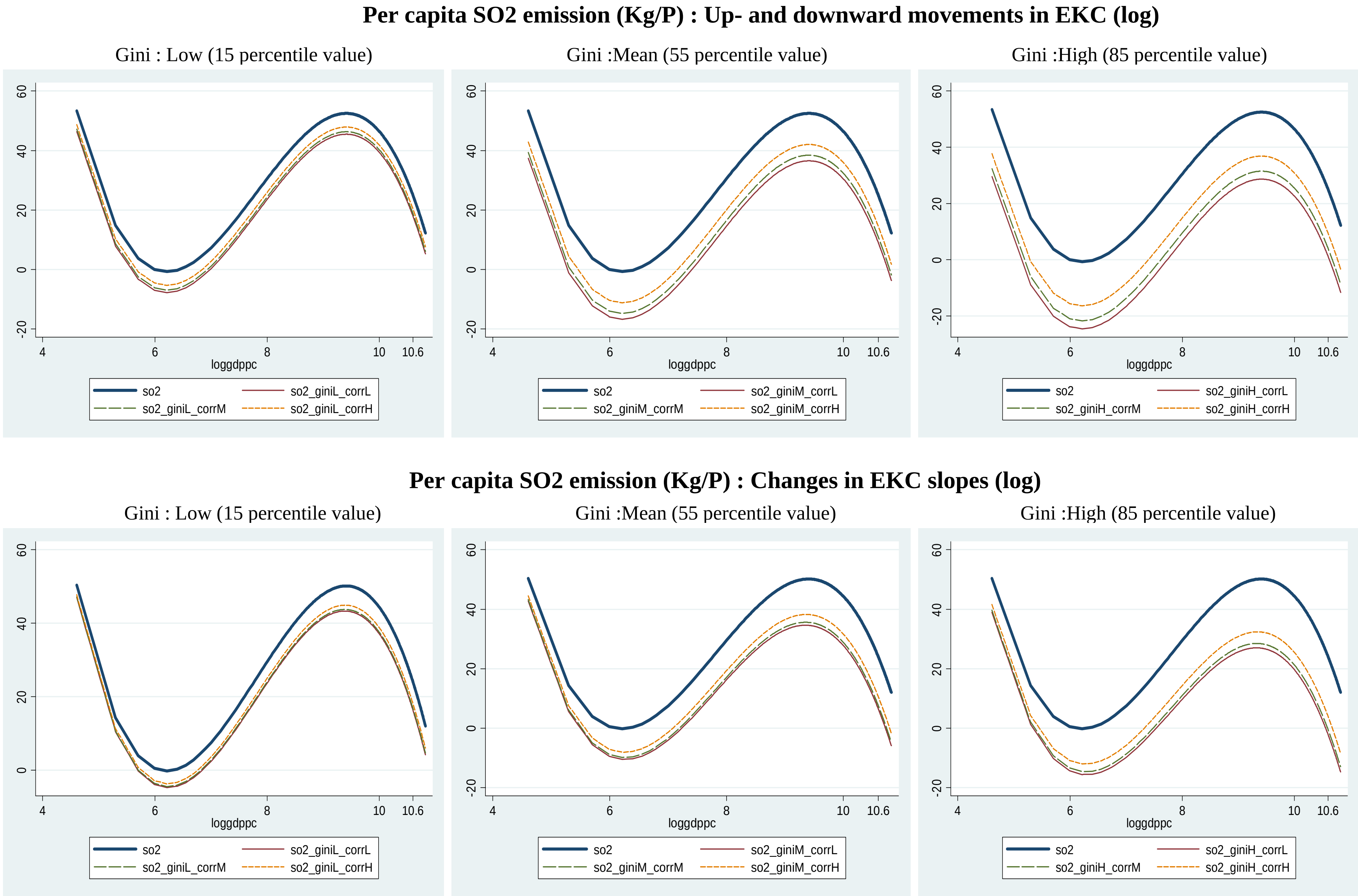
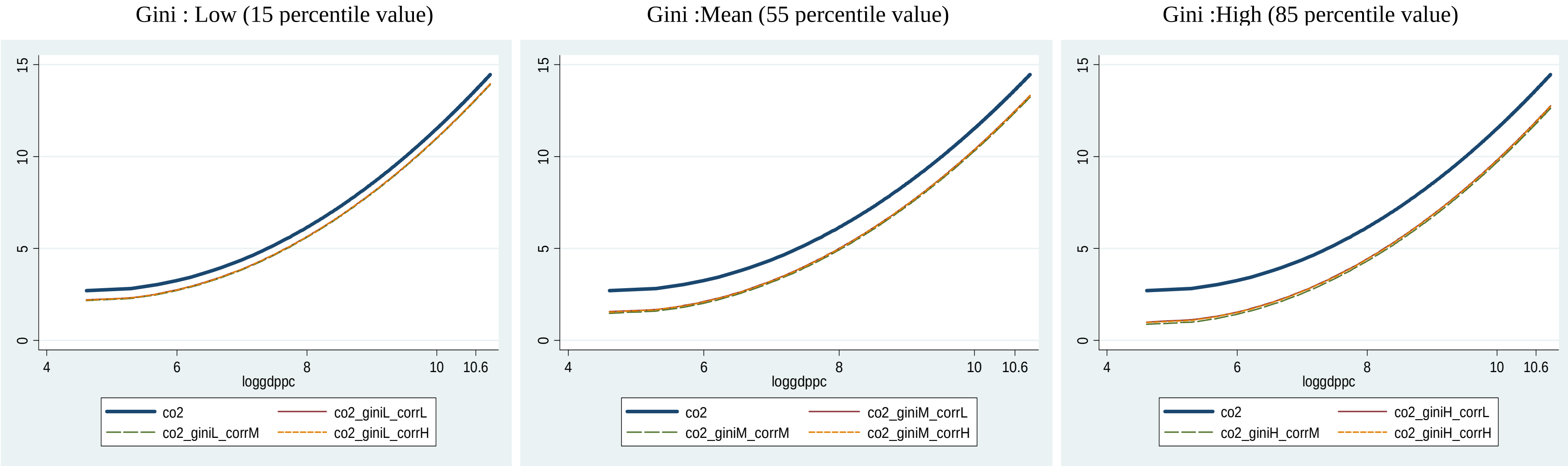


Figure B1. Augmented EKC model for per capita SO_2 emission (semi-log function)

Per capita CO2 emission (Ton/P): Up- and downward movements in EKC (log)



Per capita CO2 emission (ton/P) : Changes in EKC slopes (log)

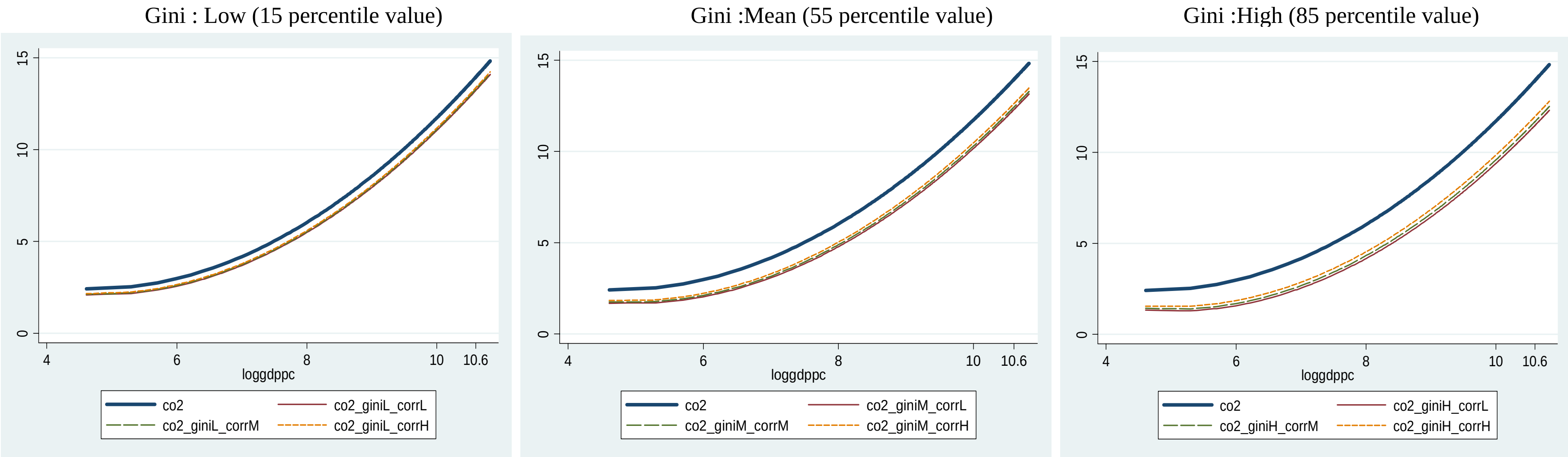
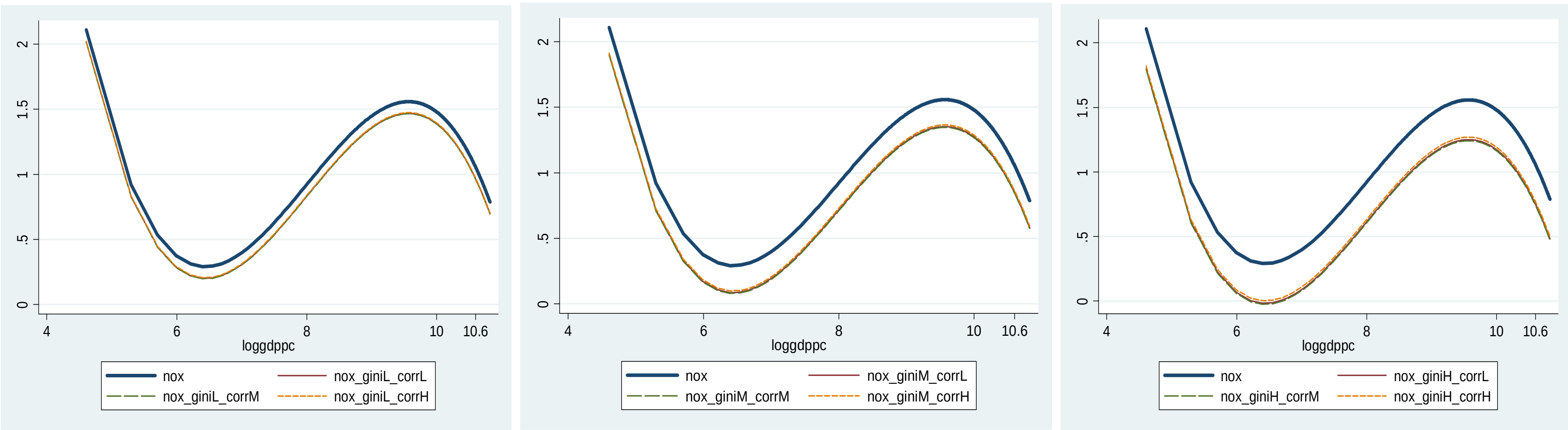


Figure B2. Augmented EKC model for per capita CO_2 emission (semi-log function)

Per capita NOx emission (Ton/P) : Up- and downward movements in EKC (log)

Gini : Low (15 percentile value) Gini :Mean (55 percentile value) Gini :High (85 percentile value)



Per capita NOx emission (Ton/g): Changes in EKC slopes (log)

Gini : Low (15 percentile value) Gini :Mean (55 percentile value) Gini :High (85 percentile value)

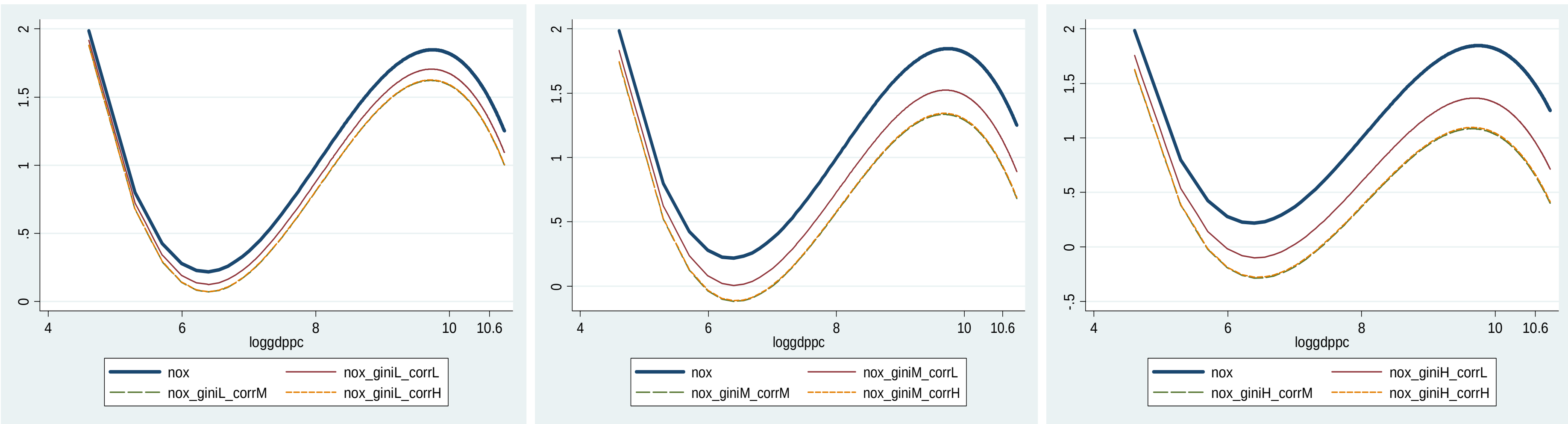


Figure B3. Augmented EKC model for per capita NOx emission (semi-log function)

Appendix C. list of countries (estimation specific sample)

Per capita SO_2 emission:

Argentina	Ecuador	Kenya	Russian Federation
Armenia	Egypt, Arab Rep.	Kyrgyz Republic	Serbia and Montenegro
Australia	El Salvador	Latvia	Singapore
Austria	Estonia	Lithuania	Slovak Republic
Azerbaijan	Ethiopia	Macedonia, FYR	Slovenia
Bangladesh	Finland	Malaysia	South Africa
Belarus	France	Mexico	Spain
Belgium	Germany	Moldova	Sweden
Bolivia	Ghana	Netherlands	Switzerland
Brazil	Greece	New Zealand	Thailand
Bulgaria	Guatemala	Nicaragua	Tunisia
Cameroon	Honduras	Nigeria	Turkey
Canada	Hungary	Norway	Uganda
Chile	India	Pakistan	Ukraine
China	Indonesia	Paraguay	United States
Colombia	Ireland	Peru	Uruguay
Costa Rica	Italy	Philippines	Venezuela, RB
Cote d'Ivoire	Jamaica	Poland	Vietnam
Czech Republic	Japan	Portugal	Zambia
Denmark	Jordan	Romania	

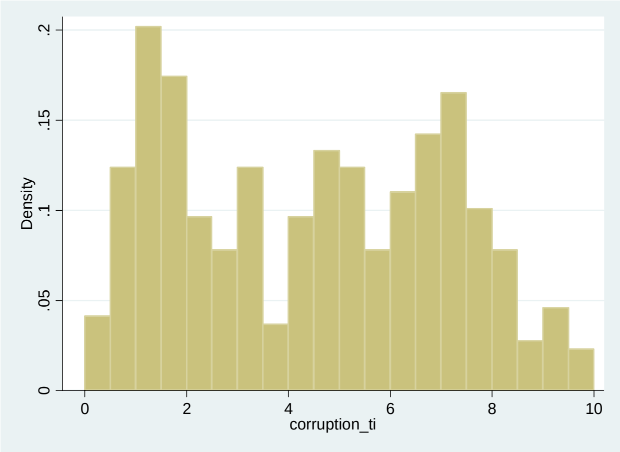
Per capita CO_2 emission

Albania	Denmark	Japan	Portugal	Venezuela, RB
Argentina	Ecuador	Jordan	Romania	Vietnam
Armenia	Egypt, Arab Rep.	Kenya	Russian Federation	Zambia
Australia	El Salvador	Kyrgyz Republic	Serbia and Montenegro	
Austria	Estonia	Latvia	Singapore	
Azerbaijan	Ethiopia	Lithuania	Slovak Republic	
Bangladesh	Finland	Macedonia, FYR	Slovenia	
Belarus	France	Malaysia	South Africa	
Belgium	Georgia	Mexico	Spain	
Bolivia	Germany	Moldova	Sri Lanka	
Brazil	Ghana	Netherlands	Sweden	
Bulgaria	Greece	New Zealand	Switzerland	
Cameroon	Guatemala	Nicaragua	Thailand	
Canada	Honduras	Nigeria	Tunisia	
Chile	Hungary	Norway	Turkey	
China	India	Pakistan	Uganda	
Colombia	Indonesia	Paraguay	Ukraine	
Costa Rica	Ireland	Peru	United Kingdom	
Cote d'Ivoire	Italy	Philippines	United States	
Czech Republic	Jamaica	Poland	Uruguay	

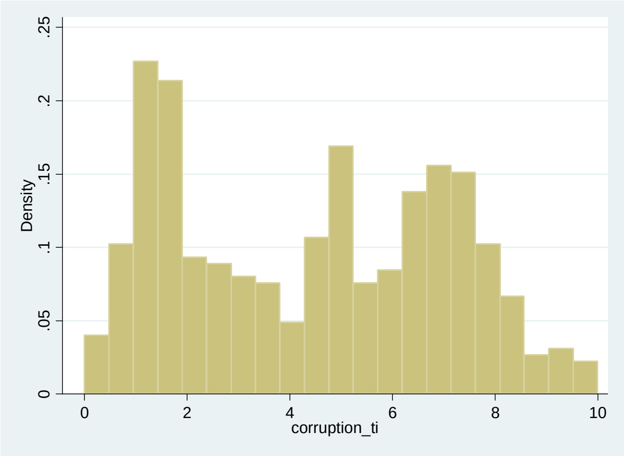
Per capita NOx emission:

Argentina	Czech Republic	Netherlands	United States
Australia	Denmark	Norway	Venezuela, RB
Austria	Ecuador	Poland	
Belgium	Finland	Portugal	
Bolivia	France	Russian Federation	
Brazil	Germany	Singapore	
Canada	Greece	Spain	
Chile	Hungary	Sweden	
China	Ireland	Thailand	
Colombia	Italy	United Kingdom	

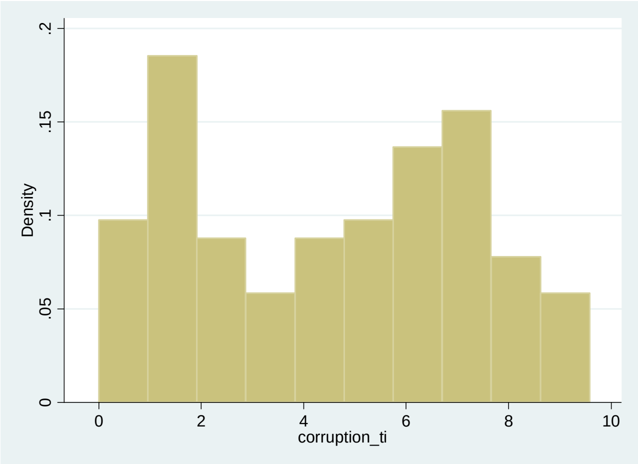
Appendix C Distribution density of corruption level



Distribution density of corruption level corresponding to the estimation of SO_2 case



Distribution density of corruption level corresponding to the estimation of CO_2 case



Distribution density of corruption level corresponding to the estimation of NOx case