The effect of corruption on carbon emissions in developed and developing countries: empirical investigation of a claim

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A R T I C L E   I N F O

A B S T R A C T

The impact of corruption on carbon emissions is one of the main objectives of empirical studies on environmental economics. Recently, a theoretical discussion was conducted on the significant impact of reducing the level of corruption on environmental quality in developing rather than in developed countries. In this study, an empirical investigation of this claim was conducted using panel data which included 61 countries, between 2003 and 2016. The effects of corruption on carbon emission were considered using a panel threshold model. The threshold variable included human development index (HDI) which divided countries into developing and developed ones endogenously. According to the results, the value of threshold ($\gamma = 0.753$) was consistent with the categorization of UNDP countries by HDI. In developing countries, for each unit of increase in the corruption index –which means a decrease in corruption levels– we observe a 0.08 unit decrease in carbon emission while carbon emission is no longer affected by the corruption levels in developed countries and decrease in corruption does not have a significant effect on carbon emission levels.

1. Introduction

The reciprocal effects of corruption and environmental quality has become the subject of empirical studies such as those of Sekrafi and Sghaier (2018), Halkos and Tzeremes (2013), Biswas et al. (2012), Lisciandra and Migliardo (2017), Hassaballa (2015), Chang (2015), and Koyuncu and Yilmaz (2009).

Corruption is defined as abuse of professional position to gain personal benefit – whether in public or private institutions – and due to the intricacies in detecting this phenomenon, various indices have been introduced for specifying its levels (Johnston, 1997; Klitgaard, 1988). Considering the fact that the structure of institution performance monitoring varies in different countries and is dependent, to a high extent, on development levels of countries, corruption levels are expected to be different across different countries. The relation between development level, measured using the HDI index, and corruption level, measured using the TI index (from zero to 10, and the greater it is, the lower the corruption level) is demonstrated in Fig. 1.

Fig. 1 represents the mean of corruption index TI against the mean of HDI index for 61 countries under investigation in the study, during the 2003–2016 interval. The TI index ranges from zero to 10, and as it approaches 10, corruption level decreases. It is worth mentioning that the

division of countries in Fig. 1 is carried out based on the threshold estimated in the study; it does not, however, differ significantly from the classification made by UNDP. In any case, regardless of this division, we can observe a positive relation between the corruption index and the HDI index, which corresponds to the negative relation between corruption level and HDI index.

On the other hand, environmental economic theories such as EKC show that higher levels of environmental quality, which can effect CO_2 emission, have a nonlinear relation with development levels of countries. The Environmental Kuznets Curve was introduced by Grossman and Krueger (1991), and later studies such as Akhbari et al. (2016), Sterm (1998), Linh and Lin (2014), Sulaiman et al. (2013), and Jalil and Mahmud (2009) have assessed this theory in different countries. This relation, in the development path of each country is considered as an inverted U shaped relation, in such a way that in preliminary stages of economic growth and development, an increasing pollutant emission is inevitable, and when the emission reaches its maximum rate, following higher economic growth rates, a decreasing flow of emission begins, and environmental quality improves due to the improvement of standards of living resulting from higher per capita GDP (Blanchard and Johnson, 2012). In order to simplify, we assume that economic growth is defined as economic development, which is not illogical, and analyzing the

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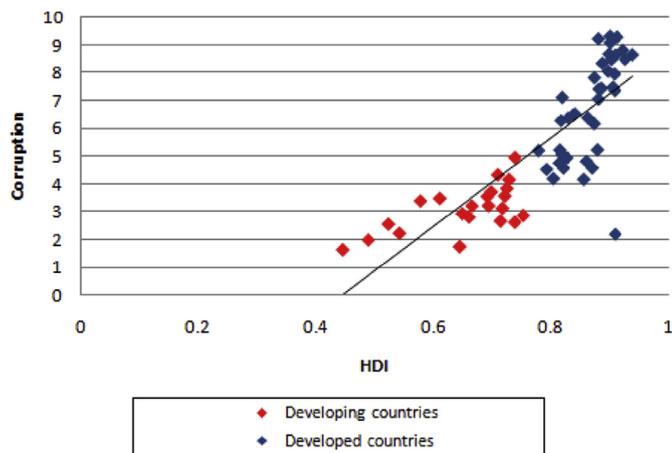
Fig. 1. The relationship between countries development and corruption index (TI).

Fig. 3. The relation between the countries GDP growth (or development levels) and carbon emission.

correlation between these two variables indicates a positive relation between them (Fig. 2).

Within the framework of EKC, we can represent the relation between pollutant emission and development levels in Fig. 3, using the mean of data from the 61 countries present in the study:

Since cross-sectional data are used to draw Fig. 3, the inverted U shape is not fully discernable. However, if a bigger sample is used, the full form of EKC can be demonstrated. Here again, regardless of the division of countries – which is done based on the estimated threshold – as the standard of living improves, we approach the turning point of the EKC curve.

Combining the concepts above, the relation between corruption levels and environmental quality is revealed. In developing and less-developed countries, due to improper monitoring structures, higher corruption levels compared to developed countries are expected, as evident in Fig. 1. High corruption levels, through flawing the performance of the economic system, maim the development process in such a way that they delay the process of achieving proper levels of development and consequently lower levels of CO2 emission and higher environmental quality. In such circumstances, the less-developed countries experience a longer interval in the upward slope of the EKC curve, while developed countries, which experience much lower corruption levels due to their effective monitoring structures, when traversing the upward slope of the EKC curve, do not face the deterring effect of corruption on the development process. Therefore, the decrease in carbon emission in developed countries is expected to occur before it does in developing (and the less-developed)
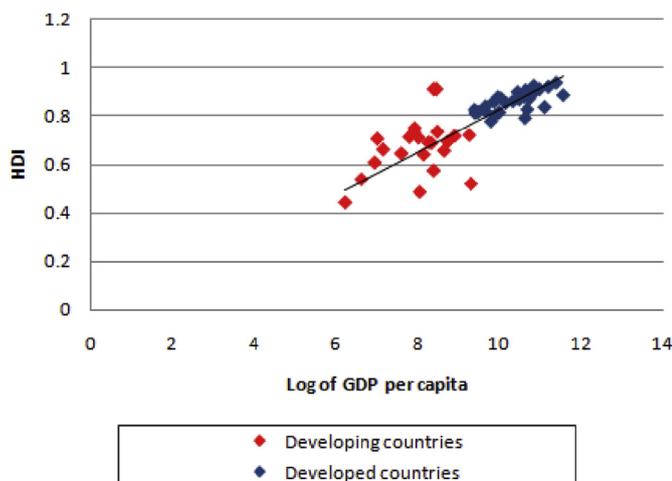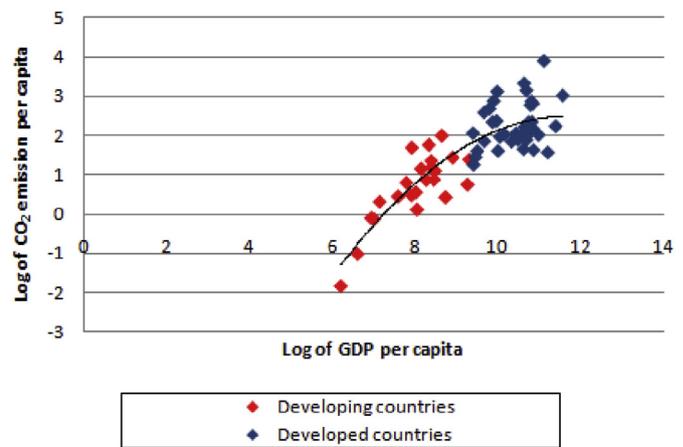
countries.

The effect of corruption on the environment can also be analyzed within the framework of the PHH theory. According to this theory, pollutant sources such as manufacturing industries lacking technologies essential for emission reduction are transferred from developed to developing and less-developed countries that have no constraints on manufacturing activities that pollute the environment in form of Foreign Direct Investment (FDI). It is evident that the defective structure of monitoring the decision-making institutions, and the probability of employees abusing their position in order to gain personal benefit can lead to the arrival of FDI in some divisions of economic activities that pursue fewer social interests compared to individual interests. Moreover, due to the fact that industries imported in form of FDI are pollutant, intergenerational interests and constant sustained development are endangered. Numerous empirical studies concerning the aforementioned theory have been conducted; these include Alhaji and Normaz (2015), Zheng and Sheng (2017), Omri et al. (2014), Kaya et al. (2017), and Gokmenoglu and Taspinar (2015).

Therefore, the corruption factor becomes one the determining factors which affect the process of environmental improvement, and reducing it will have a significant effect on the pace of economic growth and development. In this study, we seek to examine the claim that decreasing corruption levels has a significantly stronger effect on decreasing the emission of pollutants in developing and less-developed countries compared to developed countries. In other words, the coefficient of environmental quality improvement through decreasing corruption levels in countries with low levels of development is greater than that of developed countries. If this claim is proved to be true, the priority in policy making in the least developed countries regarding the improvement of environmental quality and reduction of carbon emission must be concentrated on enhancing monitoring structures to decrease corruption levels rather than mere economic growth and passing the turning point in the EKC curve. The remainder of the paper is organized as follows. The second section discusses the theory and empirical evidence. Corruption will be defined, and then, its measurement indices will be introduced. Afterwards, by clarifying the definition of corruption within a framework where it can be a determining factor in environmental quality through affecting the socio-economic relations, whether in developed or developing countries in the third section, we describes data and the adopted methodology. We empirically examine the claim that decreasing corruption in developing countries has a greater effect on carbon dioxide emission than it does in developed countries.[1] In order to examine this

Fig. 2. Correlation between countries development and standard of living.

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[1] A survey by OECD: http://www.oecd.org/daf/anti-bribery/convcombatbribery_ENG.pdf.

claim, panel data of 61 developing and developed countries during the 2003–2016 interval are used. In the model which is used, a threshold level is specified based on the human development index, which can divide the countries into two categories of developed and developing and provide the grounds for analyzing the claim regarding the nature of the effect of corruption on environmental quality in developed and developing countries. Finally, we will use fixed-effects regression with an interaction term to ensure that the previous results are correct. The last section concludes the paper.

2. Theory

Corruption is the misuse of a situation that occurs by occupations in the public sector or is generally defined as the abuse of the public resources to earn private gain. Accordingly, not only the formal public sector activity but also the activities of non-governmental agents that are profit-making can be degenerated (Johnston, 1997; Klitgaard, 1988). Because of the complexities of identifying corruption, which result from its nature, international overseeing regulatory agencies have designed indicators that rank countries (Zhang et al., 2016). Since the 1990s, several indicators have been published by international institutions such as the World Bank Corruption Index,[2] the Corruption Perception Index (CPI[3]), and the International Country Risk Guide Index (ICRG) from the Political Risk Services workgroup (PRS). These indicators usually rely on three basic sources of information which are:

1. Surveys on the corruption perception and the payment of bribes.
2. Institutional performance analysis that examines the effectiveness of management practices and roles.
3. A project audit that analyzes the divergence between expected outcomes and results from specific projects and activities.

The transparency of international organization shows that countries with lower levels of corruption, high levels of freedom of press, and easy access to information on government spending lead to strict overseeing of the performance of policymakers, which has no consequence but prevents the collusion of large businesses and policymakers in the direction of gaining private profit at the expense of trampling down social benefits.[4] Also, institutions are formed in order to support the sustainable development and rights of the next generation and the allocation of natural and environmental resources that are considered public goods in the production process, which does not disrupt distribution of intergenerational benefits (Bernauer and Koubi, 2009; Abid, 2016; Goel et al., 2013).

An explanation of the above performance will be understood by comparing the interpretations of the theoretical foundations of assumptions such as PHH and EKC in countries with high and low levels of corruption. According to the theoretical foundations of PHH, industries causing pollution in developed countries are relocated to developing countries due to the lack of environmental laws and regulations in the latter. In a condition where the level of corruption decreases due to the establishment of preventive laws, the possibility of improper utilization of the environment and natural resources for private interests is impaired, and the creation of this disorder at the national level and trade relations also does not allow the entry of foreign capital in form of environmental polluting factories. As a result, it seems unlikely that the phenomenon of pollution in the countries where corruption is minimized finds the possibility to emerge. In contrast, the existence of significant levels of corruption in developing and less developed countries has led to lower environmental standards, which ultimately lead to the entry of polluting firms (this study is empirically investigated in Candau and

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Dienesch, 2017).

On the other hand, the direct and negative effects of corruption on the quality of income distribution will postpone the change point of EKC due to the weakening of welfare levels in the society. It is obvious that at a higher than average income level in which the society demands higher levels of environmental standards, economic growth is accompanied by a reduction in emissions. Therefore, in a situation where the society suffers from high levels of corruption, corruption is expected to affect the population from two channels: a direct impact on the per capita income level and a indirect effect on the increase of pollutant emissions due to the weakness in the formation of legal and regulatory institutions. This leads to a change point for the EKC which occurs at higher income levels, which finally leads to higher levels of carbon emission and environmental degradation.

3. Background

Balsalobre-Lorente et al. (2019), Sekrafi and Sghaier (2016), Rehman et al. (2012), Cole (2007) and Sahli and Rejeb (2015) have examined the impact of different levels of corruption on EKC. These studies discovered that corruption always has a negative impact on economic growth because it reduces productivity, leads to an accumulation of additional costs, and undermines investment (Hassaballa, 2015). The direct and negative effects of corruption on the quality of income distribution which will postpone the change point of EKC, has been reviewed by Rehman et al. (2012) in Pakistan, India, Bangladesh, and Sri Lanka between 1984–2008. The results indicate that in the presence of high levels of corruption, GNP per capita at the change point of EKC is $ 998, while this amount is $ 128 more than the curve change point in a situation where corruption does not exist. The study by Leitao (2010) and Zhang et al. (2016), also confirms the transition of the change point.

The compilation of existing literature shows that through permanently affecting income distribution and the formation of regulatory bodies in society, corruption can affect the quality of the environment. On this basis, it is anticipated that the reduction in the level of corruption in all countries and at each level of development can affect the emission of pollutants. In a survey conducted by OECD, it was argued that "the effect of reducing the level of corruption on improving the quality of the environment in developing countries is greater than it is in developed countries" (Zhang et al., 2016). Theoretically, this claim justifies that the establishment of laws and the establishment of regulatory bodies within the framework of the interpretations proposed by PHH and EKC can have a significant effect on reducing the emission of pollutants. With the formation of these institutions for controlling corruption, it is logical that a continuous reduction of corruption from one level to the next will not lead to an increasing decline in pollution emissions. In other words, the quality of the environment will no longer be improved simply by reducing corruption. In such a situation, these economies are expected to be in a transition to development. Therefore, in developed countries, levels of corruption are reduced to levels where the possibility of continuous decline does not exist, and, in fact, the costs of institutionalization to reduce corruption are more than the revenues. As a result, environmental quality does not significantly follow the level of corruption, and perhaps an alternative mechanism is needed for reducing the levels of pollutants. In the following, a model is introduced for testing the above claim.

4. Methodology

To find out whether the effect of reducing corruption on improving environmental quality is greater in developing countries than in developed ones or not, the economic and environmental variables data of 61 countries between 2003 and 2016 is applied. The answer to the above question is interpreted in terms of the significance of the coefficient related to the index of corruption among the two categories of developing and developed countries. It is also a theoretical expectation that the sign

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of this coefficient is, in particular, negative for developing countries and greater than its absolute magnitude of the coefficient for developed countries. In this case, the model that answers the question is a threshold panel regression model which was introduced by Hansen (1999). The threshold shows that the slope of the regression changes before and after that. In this study, the countries are divided by the threshold variable into two groups, developed and developing economies. The following section describes the threshold variable and other variables used in the model are selected. In order to understand and validate the results of the threshold model, the relation between corruption, CO_2 emission, and development level will also be presented within the framework of a model with an interaction term.

4.1. Threshold model

Hansen (1999) presented a threshold regression equation for balanced panel in the following form:

$$y_{it} = \mu_i + \beta_1' x_{it} I(q_{it} \leq \gamma) + \beta_2' x_{it} I(q_{it} > \gamma) + e_{it} \tag{1}$$

Threshold variable is denoted by q_{it} and γ represents the value in which regime change occurs. Then, the observations are divided into two regimes, depending on whether the threshold variable q_{it} is smaller or larger than the threshold γ. The regimes, as mentioned by Hansen (1999), are distinguished by differing regression slopes, β_1, β_2. For the identification of β_1 and β_2, it is required that the elements of x_{it} are not time invariant. Also, it is assumed that the threshold variable q_{it} is not time invariant. The error term e_{it} is assumed to be independent and identically distributed (iid), with zero mean and finite variance σ^2. Finally, for any given γ, the slop coefficient β can be estimated using OLS which is written as follows:[5]

$$\hat{\beta}(\gamma) = (X^*(\gamma)'X^*(\gamma))^{-1}X^*(\gamma)'Y^* \tag{2}$$

4.1.1. Testing for a threshold

Hansen (1999) mentioned that it is important to determine whether the threshold effect is statistically significant. The hypothesis of no threshold effect in Eq. (1) can be represented by the linear constraint:

H0. $\beta_1 = \beta_2$

Under H_0 the threshold γ is not identified, so classical tests have non-standard distributions. Under the null hypothesis of no threshold, the model becomes:

$$y_{it} = \mu_i + \beta_1' x_{it} + e_{it} \tag{3}$$

After making the fixed-effect transformation, we have:

$$y_{it}^* = \beta' x_{it}^* + e_{it}^* \tag{4}$$

The regression parameter β_1 is estimated using OLS, yielding estimate $\tilde{\beta}_1$ and residuals $\tilde{e}_{it}^*$ and sum of square errors $S_0 = \tilde{e}^{*'}\tilde{e}^*$. The likelihood ratio test of H_0 is based on the following expression:

$$F_1 = (S_0 - S_1(\hat{\gamma}))/\hat{\sigma}^2 \tag{5}$$

Hansen (1996) suggested a bootstrap procedure for the construction of P-value. Finally the null hypothesis of no threshold effect is rejected if the P-value is smaller than the desired critical value.

4.1.2. Multiple threshold test

The regression model (1) was assumed to have a single threshold. In some applications, multiple thresholds may be encountered. For example, a two-threshold model is written as follows:

$$y_{it} = \mu_i + \beta_1' x_{it} I(q_{it} \leq \gamma_1) + \beta_2' x_{it} I(\gamma_1 < q_{it} \leq \gamma_2) + \beta_3' x_{it} I(\gamma_2 < q_{it}) + e_{it} \tag{6}$$

So that $\gamma_1 < \gamma_2$.

Since the model used in this study has a threshold, for studying of the estimation method and the testing the existence of multiple thresholds, Hansen (1999) is referred to.

4.1.3. Determining the number of thresholds

Eq. (6) can be linear and has no threshold or one or two thresholds. Previously, F_1 was introduced as a statistic for the absence of threshold. If F_1 rejects the null hypothesis, then another test will be required to determine the existence of one or two thresholds. Minimizing the sum of squared errors from the second threshold estimate is given as $S_2^r(\hat{\gamma}_2^r)$ with variance estimate $\hat{\sigma}^2 = \frac{S_2^r(\hat{\gamma}_2^r)}{n(T-1)}$.

Therefore, an approximate likelihood ratio test of one versus two thresholds can be defined as follows:

$$F_2 = \frac{S_2(\hat{\gamma}_1) - S_2^r(\hat{\gamma}_2^r)}{\hat{\sigma}^2}$$

The hypothesis of one threshold is rejected in favor of two thresholds versus the two if F_2 is large.

5. Materials and methods

In this study, to examine the greater impact of reducing corruption on improving the quality of the environment in developing countries rather than developed countries, a model which demonstrates the impact of reducing corruption on the level of pollutant emissions is designed. For this purpose, the basic model which estimated the environmental Kuznets curve in several studies is extended, including Zhang et al. (2016) and Cole (2007). Before describing this model, data description is presented.

5.1. Data description

The source of variables including Panel data of 61 countries[6] from the period of 2003–2016 are presented in Table 1. These countries were selected randomly from OECD and MENA[7] countries but in the selection procedure we made sure that only developed (or only developing) countries were not selected.

In this study, CO_2 emissions is a proxy to determine environmental quality. According to the necessity of country classification into developed and developing countries, an indicator is needed to determine the extent of development. Since development has a multi-dimensional concept, the Human Development Index (HDI) is used, which is between 0 and 1 (the closer to one, the greater human development). According to the United Nations Development Program (UNDP), the Human Development Index is a composite indicator that includes life expectancy at birth, average school years, the expected time for education and per capita income that shows the possibility of a healthy and prolonged life, the ability to acquire knowledge and ability to achieve standards of a desirable life, respectively.

Other variables used include GDP per capita at constant prices in 2010, the corruption index, which is between 0 and 10 (closer to 10, lower levels of corruption), the urban population growth rate, the share of trade Commodity of GDP and primary energy consumption. Table 2 shows the statistical characteristics of each of the variables used in the

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[5] The econometric procedure of calculating X* and Y* presented by Hansen (1999).

[6] The list of these countries presented in appendix.
[7] Middle East and North Africa.
[8] Energy information administration.
[9] World development index.
[10] United nation development program (http://hdr.undp.org/en/data#).4r

Table 1
Variable definition and data sources.

Variable	Definition	Unit	Data source
CO$_2$	Logarithm of per capita CO$_2$ emissions from the energy consumption	Million tones	EIA[8]
Y	Logarithm of per capita GDP	Constant 2010 US$	WDI[9]
E	Logarithm of per capita total primary energy consumption	Metric tons of oil equivalent per capita	EIA
Tr	The sum of exports and imports of goods measured as a share of GDP	% of GDP	WDI
upop	Rate of urban population growth	Annual %	WDI
corr	Corruption index from 0 (highest level of corruption) to 10 (free of corruption)	-	Transparency.org
HDI	Human Development Index from 0 (worst situation) to 1 (highest level)	-	UNDP[10]

model.

5.2. Model design

Variables introduced in Table 2 are commonly used in models related to the environmental economy. In this study, for the empirical test of the claim proposed by OECD, the threshold model is estimated as follows:

In the above equations, i is the index of the country and the index t represents the time. Using the dependent and explanatory variables as shown in Table 2, the threshold panel model is presented as follows:

$$CO_{2_{it}} = \begin{cases} \alpha + \varphi_1 y_{it} + \varphi_2 y_{it}^2 + \varphi_3 y_{it}^3 + \varphi_4 HDI_{it} + \varphi_5 E_{it} + \varphi_6 Tr_{it} + \varphi_7 pop + \beta_1 corr_{it} + e_{it} & hdi_{it} \leq \gamma \\ \alpha + \varphi_1 y_{it} + \varphi_2 y_{it}^2 + \varphi_3 y_{it}^3 + \varphi_4 HDI_{it} + \varphi_5 E_{it} + \varphi_6 Tr_{it} + \varphi_7 pop + \beta_2 corr_{it} + e_{it} & hdi_{it} > \gamma \end{cases}$$

$$CO_{2_{it}} = \alpha + \varphi_1 y_{it} + \varphi_2 y_{it}^2 + \varphi_3 y_{it}^3 + \varphi_4 HDI_{it} + \varphi_5 E_{it} + \varphi_6 Tr_{it} + \varphi_7 pop + \\ \beta_1 corr_{it} I(hdi_{it} \leq \gamma) + \beta_2 corr_{it} I(hdi_{it} > \gamma) + e_{it}$$

(7)

So that I(.) is an indicator function. As already mentioned, HDI is used as the threshold that separates countries into developed and developing economies. The analysis of the coefficients obtained from the estimation of the above model provides answers to the main question.

5.3. Estimation

The first step in estimating the model is to determine the number of thresholds. Table 3 summarizes the F test results that determine whether the model is linear or not and whether it has more than one threshold or not.

The result of the F test indicates that the hypothesis of the absence of a threshold is rejected, but the statistics for the second and third thresholds indicate that the null hypothesis is not rejected for the related tests. Evidence suggests that only one threshold and two regimes exist. Accordingly, the one-threshold model (7) is estimated. Based on the estimation, a country whose human development index exceeds 0.753 is among the developed countries, and countries with a corresponding index less than 0.753 is in the category of developing and less developed countries.

Depending on the extent of development, United Nations Development Program (UNDP) represents different categories of countries. This

Table 2
Summary of descriptive statistics.

Variable*	Min.	Max.	Mean	Standard error
CO$_2$	-3.5857	4.1017	1.6655	1.1035
Y	5.8974	11.6259	9.5195	1.3402
E	-4.0471	12.1799	6.0773	3.6029
Tr	2.8447	5.1978	4.0956	0.5001
upop	-2.1876	16.6064	2.0428	2.2091
corr	-0.2231	2.2721	1.5814	0.4920
HDI[1]	-0.9649	-0.0512	-0.2588	0.1812
hdi[2]	0.381	0.95	0.783	0.126

* All data are in logarithmic form except "hdi".
[1] Used as an explanatory variable.
[2] Used as threshold variable. In this situation the data of the "hdi" are not in logarithmic form.

division was done using HDI, which is defined in Table 4.

It is obvious that the estimated threshold is consistent with the measure of HDI which is presented in Table 4, because the threshold value of 0.753 is between 0.819 and 0.631 which splits the countries into developed and developing ones.

The results of estimating Eq. (7) are presented in Table 5.

Overall, the results in Table 5 show the significance of the regression and the coefficients.

5.4. Alternative model (with interaction term)

In analyzing the effects of corruption on emission levels, we can define a model such the one below in order to validate the threshold model coefficients and have a better understanding of the aforementioned effects.

$$CO_{2_{it}} = \alpha + \beta_1 y_{it} + \beta_2 E_{it} + \beta_3 Tr_{it} + \beta_4 corr_{it} + \beta_5 (corr_{it} \times hdi_{it}) \\ + \beta_6 (corr_{it} \times hdi_{it}^2) + \beta_7 pop_{it}$$

(8)

Estimation of the Eq. (8) considering fixed effects reveals the following outcomes (see Table 6):

A variable labeled MCC (marginal effect of corruption on CO$_2$ emissions), which shows the final effect of decreasing corruption on pollutant emission in different levels of development based on the value of hdi is defined. In order to calculate this effect, we derive relation (9):

$$\frac{\partial CO_{2_{it}}}{\partial corr_{it}} = \beta_4 + \beta_5 hdi_{it} + \beta_6 hdi_{it}^2 = MCC$$

(9)

Drawing the MCC curve proves the non-linear relation demonstrated using the threshold model, and validates previous findings.

Two points can be drawn from Fig. 4. First, the value of HDI index at the MCC curve turning point is equal to 0.762, which does not differ significantly from the threshold extracted from the previous model and the threshold which UNDP specifies as the country division threshold.

Table 3
Test of determining the number of thresholds.

Null hypothesis	F stat	P-value	Critical value (10%, 5%, 1%)
Linearity versus on threshold	54.26	0.01	35.06, 40.89, 59.40
One versus two threshold	35.16	0.11	34.7, 42.05, 59.20
Two versus three treshold	28.57	0.39	45.74, 54.33, 71.44

Table 4
Country classification in terms of HDI 2015.

Development status	HDI
Developed countries*	0.819
Medium development countries	0.631
Low development countries	0.497

Source: UNDP.
 * This category includes high and very high developed countries which are defined by UNDP. In this study, these two groups are merged and the average of related HDI calculated to be equal to 0.819.

Table 5
Estimation results.

Variable	coefficient	t stat	p>|t|
Y^3	0.06	12.13	0.000
Y^2	-1.72	-13.29	0.000
Y	16.37	14.64	0.000
E	0.67	37.25	0.000
Tr	0.04	1.98	0.048
HDI	-1.07	-5.94	0.000
pop	0.007	2.32	0.021
Corr: (hdi ≤ 0.753)	-0.081	-2.62	0.009
Corr: (hdi >0.753)	0.044	1.35	0.177
α	-54.56	-17.15	0.000
F(60,784) = 299.76		Prob > F = 0.000	

Table 6
The results of fixed effect model.

Variable	Coefficient	t-stat	p>|t|
Y	0.143	3.51	0.000
E	0.671	29.59	0.000
Tr	0.168	6.87	0.000
corr	-3.181	-10.07	0.000
corr $\times$ hdi	8.420	10.06	0.000
corr $\times$ hdi^2	-5.523	-10.13	0.000
pop	0.009	2.90	0.004
α	-4.408	-12.35	0.000
F(60,784) = 245.34		Prob > F = 0.000	

Second, according to the graph, which is drawn based on relation 10 using the mean values of HDI data of 61 countries against the MMC-calculated values, in lower levels of development (red points) the effect of decreasing corruption (which leads to an increase in the TI index) on decreasing CO_2 emission is stronger than it is in higher levels of development. By improving the level of development, and approaching more developed countries (green points), the final effect of corruption on pollutant emission decreases, and approaches zero. This shows the insignificance of the corruption level factor as a factor which decreases carbon emission in developed countries, which is in accordance with the insignificance of the estimated coefficient for the corruption variable related to developed countries. It should be noted that the value of the corruption index TI has an inverse relation with corruption level, which means that as it approaches 10, the level of corruption decreases.

5.5. Interpreting the results

From Table 5, EKC is established because, in accordance with the theoretical foundations of this hypothesis, it is expected that the coefficient of GDP will be negative while the coefficient of the GDP square is positive. The sign of these coefficients indicates that the emission of pollutants with the income level has a positive relation until the amount of emission reaches its maximum and then proceeds to the opposite trend. On the other hand, the significance of cubic form of GDP per capita indicates that once the pollution emission decreases, with the increase in

the level of income, a change in the direction of its propagation and ascendancy will occur. This pathway shows that in developed countries, after the improvement of technology and the formation of regulatory bodies at certain levels of GDP, this will help stop the increasing emissions of pollutants and generate a declining trend in emissions. After that, at certain levels of GDP, the pressure on natural resources increases again, and it seems that there is no longer any possibility of economic growth without harming the environment. In such a situation, growth is only possible at the expense of reducing the quality of the environment.

The energy consumption coefficient is positive and significant. Obviously, the use of fossil fuels increases CO_2 emissions.

Having a positive and relatively weak significance of trade in goods is justified by linking development and growth of industrial production and the further emission of environmental pollutants. Relatively weaker significance of this factor is due to the set of studied countries which includes developed and industrialized countries, as well as developing and non-industrial countries. If the model was estimated only for industrial countries, there would have been increase in the significance of this coefficient.

In Table 5, the coefficient of the HDI variable is negative and statistically significant. The HDI index is a measure that reflects both the quantitative and qualitative aspects of human life. On the other hand, it is used as a benchmark for determining the level of development. It is expected that improving the level of HDI by improving the levels of per capita income and improving the educational status, and promoting human capital will affect the quality of the environment. Therefore, in the trend of the incremental per capita income, which according to the EKC hypothesis a reduction is observed in carbon emissions, part of the downward trend in emissions is interpreted from the HDI improvement Channel. On the other hand, by enhancing human capital through the promotion of the quality of education that is included in the HDI index, improvements will be observed in labor productivity and new methods of production using new technologies, which will both increase the productivity of the production factors and also have fewer pollutants. This path can also justify the inverse relationship between HDI and CO_2 emissions.

Although the urban population growth variable is significant, it has a small effect on CO_2 emissions. The relationship between urbanization and the increase in emissions of pollutants is explained by the fact that the increase in urban population from two paths can affect the increase in pollutant emissions. On one hand, the growth in urban population leads to an increase in demand for consumer goods, which by pressure on natural resources as one of the factors of production, can reduce the quality of the environment. On the other hand, urban development, due to population growth, increases the demand for urban transport, which in most cases and at least in the short run increases the use of personal vehicles. This procedure directly affects air pollution and environmental degradation, especially in cities, which of the two above channels has a greater impact on environmental pollution, and is related to the degree of development of countries. First of all, it seems that in developed countries, due to the distribution of facilities between different regions and having higher than the average per capita income, the process of migration to cities has reduced drastically, and secondly, in developed countries, there are institutions with the objective of preventing the destruction of the environment by supervising and legislation. The consequence of these two events is that in developed countries it is unlikely that emission of pollutants will increase in urban population due to an increase in demand for personal vehicles. On the other hand, in the developing and less developed countries, the process of evacuation of villages and migration to cities which results from lack of balance and proportionality in the distribution of amenities and relatively high disparity in income distribution among the regions, is continued which is also followed by both demand for consumer goods and demand for vehicles, which is on the increase and ultimately, this adds to the amount of pollutants. The small coefficient related to the urban population growth rate is attributed to the poor overcoming of the impact of reducing
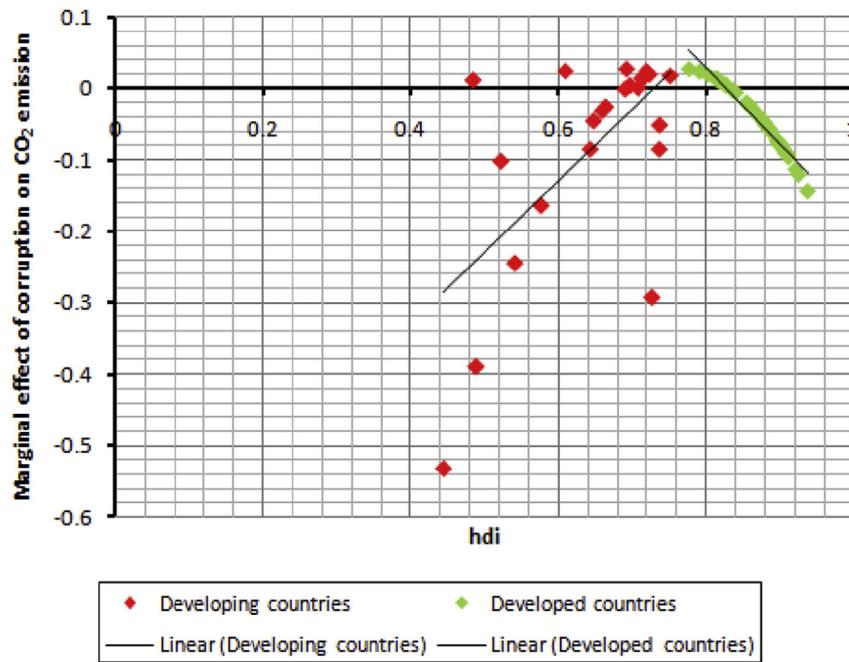
Fig. 4. Marginal effect of corruption on CO2 emission.

emissions in developed countries relative to the increasing trend of emissions in developing ones.

Based on theoretical foundations, the level of corruption coefficients in both regimes is well justified. According to the claim of OECD about the different intensity of the effects of corruption on carbon emissions in developing and developed countries, the improvement of the corruption index has a more powerful effect on reducing carbon emissions. Estimates have shown that the coefficient related to the effect of reducing corruption on pollutant emissions in developed countries is positive but not statistically significant. It implies that in these countries the level of corruption has reached a level that does not have a positive effect on the quality of the environment. This implies that at such levels of development, the contribution of other factors rather than corruption determines the carbon emission level. In other words, corruption in these countries has reached its minimum level, and as a result, the effectiveness of

environmental quality from the level of corruption has ceased. As demonstrated in Fig. 4, which is extracted from the alternative model with fixed effects, when development levels increase, the final effect of corruption on carbon emission is close to zero.

Fig. 5 is drawn using the threshold model and mean values of the corruption and CO_2 emission index related to the 61 countries during the specified interval.

The red points represent the developing and less-developed countries, and blue points represent the developed countries. These countries were divided based on the estimated threshold for the HDI index. Two points can be inferred from this graph. The first is related to the positive relation between the corruption index and the CO_2 emission index across the countries, represented by red points, while the coefficient of the effect of corruption on emission in these countries is estimated to be negative based on the threshold model, which can be confusing. We need to
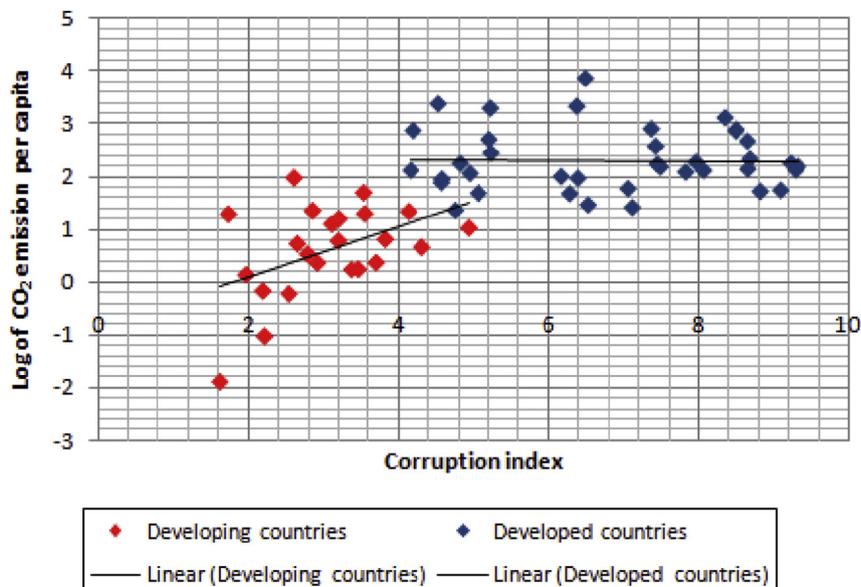

Fig. 5. Threshold model.

consider the fact that an increase in the corruption index means a decrease in corruption level, and therefore, the positive relation between an increase in the index and emission indicates a negative relation between corruption level and CO_2 emission, which is proved by the results. The second is related to the higher sensitivity of pollutant emission across developing and the less-developed countries to the changes in corruption levels, compared this sensitivity in developed countries, which can be assessed based on the slope of the trend line. By dividing the countries based on the estimated threshold for HDI, the coefficient of the corruption index for the developed countries was estimated as positive and insignificant, and this is reflected in Fig. 5, in the horizontal trend of data related to these countries, which shows the insensitivity of carbon emission to changes in corruption levels. In analyzing this relation, it was mentioned that other factors determine the emission levels in these countries. On the other hand, this sensitivity, based on the slope of the trend line, is significant across the developing and less-developed countries, and this is in complete accordance with the estimated coefficient for the corruption index in the threshold model.

6. Discussion

An overview of the literature suggests that various aspects of human life are affected by corruption. The studies show that the spread of corruption increases inequality by disrupting income distribution. The other aspect of corruption effectiveness stems from environmental degradation, which may not be as tangible as its effectiveness on the distribution of income - at least in the short term.

The misuse of public resources for private gain, which is known as opportunistic behavior and corruption, interprets in the context of hypotheses such as EKC or PHH, which ultimately by reducing social and economic costs, will speed up environmental degradation. For example, corruption leads to disruptions in the functioning of regulatory bodies and the ineffectiveness of regulations that are designed to control opportunistic behavior which harms the environment. This shifts the change point of EKC to the higher levels of incomes which leads to increased emissions and environmental degradation, and ultimately have a negative impact on sustainable development.

In this regard, based on a claim it is suggested that a reduction in level of corruption in developing countries compared with developed countries, has a more powerful effect on the growing trend of emissions (Zhang et al., 2016). The theoretical basis is that levels of corruption in developed countries have reached their minimum levels due to the establishment of regulatory institutions, so that a further reduction in the level of corruption is extremely costly. These modest changes in the level of corruption will not have a significant effect on the reduction of carbon emission level, and the reduction of environmental pollutants depends on the improvement of other factors. By contrast, developing and less developed countries still experience high levels of corruption, due to lack of formation of regulatory institutions and the absence of corrective legislation opportunistic behavior. In such a situation, within the framework of the PHH, this will cause environmental degradation and increase in pollutants in developing countries. The absence of preventive and restrictive rules on destructive economic activities leads to a low cost of manufacturing polluting activities, followed by transferring of capital

in form of dirt industries from developed countries. According to this hypothesis, such a procedure merely leads to degradation of the environment in developing and less developed countries.

Some institutionalization such as the establishment of an independent judiciary in these countries, which deals with corrupt and opportunistic behaviors, can significantly reduce levels of corruption. Since natural resources in the production process are known as one of the factors of production, its use at a lower cost can result in less costly production and higher profits. If the rules are well implemented, so that the emission of pollutants from the process of production and destruction of natural resources imposes a significant cost to the manufacturer, then the environmentally destructive process of production will be significantly modified and consequently significant reduction in the emissions of pollutants.

In short, if developing countries seek to improve the environment, policies should be put in place to reduce the level of corruption while due to marginal levels of corruption (equal to higher value corruption index (TI)), this will not work properly in developed countries.

Declarations

Appendix. Countries which were used:

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Developing countries*	Afghanistan, Angola, Bangladesh, Bolivia, Brazil, China, Colombia, Algeria, Ecuador, Egypt, Indonesia, India, Iran, Iraq, Jamaica, Jordon, Lebanon, Morocco, Mongolia, Pakistan, Tunisia, Turkey, Yemen.
Developed countries*	United Arab Emirates, Australia, Austria, Belgium, Bahrain, Canada, Switzerland, Chile, Czech Republic, Germany, Denmark, Spain, Estonia, Finland, France, United Kingdom, Greece, Hungary, Ireland, Israel, Italy, Japan, Korea, Kuwait, Luxemburg, Latvia, Netherland, Norway, New Zealand, Oman, Poland, Portugal, Qatar, Saudi Arabia, Slovakia, Slovenia, Sweden, USA.

*Countries were categorized by UNDP HDI.

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