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Socio-economic determinants of environmental degradation: Empirical evidence for the Environmental Kuznets Curve

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Abstract

The aim of the paper is to examine socio-economic determinants of environmental degradation. The empirical study employs quantile regression which enables separate predictions for different levels of the dependent variable to be made. This study investigated 62 countries from low, middle and some high income countries for 1995–2019. The Environmental Kuznets Curve (EKC) is verified for the aforemented countries in analyzing the relationship between economic growth and carbon emissions using quantile regression. The study also revealed that the schooling rate has a pollution-increasing effect. In addition to the reducing effects of trade openness, democracy, and economic freedom variables on environmental degradation, the opposite effect of life expectancy at birth is observed, increasing environmental degradation. In this context, this paper concluded that the EKC hypothesis is not supported. The government should encourage pollution-reducing policies in low and middle income countries.

Keywords

- environmental degredation
- economic development
- EKC
- panel data
- quantile regression

JEL codes: O11, O13, O44

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Introduction

Environmental degredation throughout the world has prompted an increasing number of scholars to look into the reasons. Environmental changes and their driving forces, such as economic growth and environmental degredation, have a complicated connection (McPherson & Nieswiadomy, 2005).

An important indicator of environmental degredation has been acknowledged as CO_2 emissions. While energy production-based CO_2 emissions were 20,516.0 Mt CO_2 in total in the 1990s, this figure increased to 33,513.3 Mt CO_2 in 2018 (IEA, 2021). While the world average of CO_2 emissions was 3.12 tons per capita in 1960, this figure peaked at 4.70 tons in 1979 and was 4.48 tons in 2018. It is known that developed countries make the highest contributions to these averages. For example, while the global greenhouse gas emission per capita of the USA was 16 tons in 1960, it increased to 22.51 tons in 1973 and decreased to 15.24 tons in 2018 (World Bank, 2021). Still, United States is responsible for 24% of the global emissions (Buks & Sobański, 2023).

Continuous research is carried on finding out the determinants of environmental degredation and how they affect the environment. In this study, 62 low-, middle-, some high-income countries with available data were examined between 1995-2019. In order to extend the previous literature the number of variables was increased and the hypotheses with different and current methods was tested. Furthermore, the ecological footprint and carbon emissions are the two most commonly cited indices of environmental degradation. Carbon emissions were utilized as an indication of environmental degredation in this study.

Economic issues such as energy, production, foreign trade and education have recently been added to the long-established theoretical foundation and have been associated with environmental degradation (e.g., Anwar, Sinha et al., 2021; Sun, 2022; Voumik et al., 2023). This study aims to enrich the literature by adding the total carbon emissions of countries, per capita income level in 2015 constant prices, the second and third power of income per capita, average schooling rate, trade openness, average life expectancy, democracy, and economic freedom index to the model.

The main focus of this study is to reveal the effects of the main socioeconomic variables reflecting the increase in welfare in low and middle-income and some high-income countries on pollution. The most important questions to ask at this point:

1. How does the level of income per capita, which represents the increase in welfare, affect pollution and what are the dimensions of this effect?
2. What is the relationship between average schooling and pollution-representative carbon emissions?
3. How does trade openness affect pollution?
4. As an output of the economic development process, what is the effect of life expectancy at birth on pollution?
5. How do changes in variables such as democracy and economic freedom as representatives of economic and social life affect carbon emissions as a representative of pollution?

With the above items the study's research questions are formulated and the results emerge to support the claims put forward here. Policy recommendations are evaluated by calculating pollution projections and turning points in line with the results.

The remainder of the paper is organized as follows: Section 1 provides an overview of the theoretical and empirical literature. Section 2 presents the data and methods. Section 3 discusses empirical findings and results. The final Section contains discussion, concluding remarks and limitations of the study.

1. Literature review

1.1. Theoretical literature review

Kuznets (1955) discovered that income inequality initially impedes economic growth as measured by GDP per capita but that after economic growth reaches a certain level, income inequality tends to diminish. This trajectory reveals the "Kuznets Curve," an inverted U-shaped link between income distribution and economic growth. However, as a result of the emergence of a relationship similar to an inverted U shape between income level and environmental degradation, this concept has gained importance for the environment and energy economics literature.

Another inequality-environmental degradation channel is theoretically related to Veblen (1934) effect. This theory proposes that the rich consume expensive items and services that are very visible to the public in order to attain status or favour. This indicates that increased inequality may lead to increased consumption competition (Schor, 1998) resulting in more emissions. In other words, as a results of inequality, working hours' increase. These increased hours mean increasing consumption of energy and carbon emissions (Aye, 2020; Fitzgerald et al., 2015; Knight et al., 2013).

1.2. Empirical literature review

1.2.1. Literature regarding environmental degredation-education nexus

In empirical literature there are many studies that investigate the impact of education on environmental degra dation, particularly in developing countries. For example, using GMM-System panel technique, Romuald (2010) found that while education is not a main factor in the increase of carbon dioxide emissions, it is a factor in the growth of pollution however the effect is mitigated by the presence of political institutions in 85 countries. Similarly, Fotourehchi (2017) states that the education level decreases environmental pollution through a strenghtening of environmental public pressure and awarenesss in developing countries using panel data between 1999 and 2014. Alkhateeb et al. (2020) examined the influence of education on CO_2 emissions in Saudi Arabia from 1971 to 2014. They revealed that primary education could not affect CO_2 emissions but secondary education reduces the environmental degradation. Thus they opined that improving higher education activities in Saudi Arabia helps to avoid negative consequences on the environment. Similarly, Zhu, Peng et al. (2021) asserted that expanding the higher education scale and enhancing the higher education quality may help reduce carbon emissions in China. Employing the de Kónya method Aytun and Akın (2021) investigated the association between education and CO_2 emissions in fourteen developing nations from 1990 to 2017. The findings revealed a link between education and CO_2 emissions in Chile and Poland. Because these nations had the greatest levels of education and income in the research the authors stated that education policy may be viewed as a critical strategy in mitigating environmental pollution. Eyuboğlu and Uzar (2021), asserted that higher education can be used to overcome environmental problems for Turkey after testing higher education and CO_2 data by ARDL technique during the period 1983–2017. Finally, Hassan, Batool et al. (2022) calculated the impact of education on carbon emissions in BRICS nations between 1990 and 2015. They found that education considerably improves environmental quality and diminishes energy poverty indirectly.

Recently studies can be found regarding the effects of online education amid the COVID-19 pandemic. For example, Yin et al. (2022) showed that online education can significantly reduce energy consumption and lower carbon emissions due to less usage of transportation and electricity consumption in Chinese universities.

In general, there is a strong belief in the newest literature that increasing the quality of education will reduce carbon emissions and improve air quality (e.g., Eyuboğlu & Uzar, 2021; Hassan et al., 2022; Khan, 2020; Zhu, Peng et al., 2021). As a counter finding, O'Neill et al. (2020) found that improving educational quality causes s a modest net increase in carbon emissions but significantly improves Human Development Index values which is an indicator that correlates with the adaptive capacity to climate impacts in developing countries. This result indicates that the relationship between education and carbon emissions is worth examining.

1.2.2. Literature regarding environmental degradation-economic growth nexus

According to the empirical literature the dynamic impacts of development on environmental quality are being investigated to assess the validity of the Environmental Kuznets Curve (EKC). The first studies on this subject belong to Grossman and Krueger (1991) and Holtz-Eakin and Selden (1995) who mentioned the existence of an inverse relationship between economic growth and environmental quality. Studies following those aforementioned and testing the validity of EKC can be grouped into three categories.

In the first category, there are studies that do not support the EKC view. For example, Fodha and Zaghdoud (2010) investigated the relationship between economic growth and carbon emissions for Tunisia during the period 1961–2004 using time series data and cointegration analysis. They observed a monotonically increasing linear nexus between per capita GDP and per capita CO_2 emissions. Thus they rejected the validity of EKC for Tunisia. Ozturk and Acaravci (2010) identified an N-shaped association between economic growth and carbon emissions in Turkey using the ARDL bounds testing technique from 1968 to 2005. Similarly, Pal and Mitra (2017) examined the CO_2 emissions-growth nexus by making a comparative analysis between China and India for the years 1971–2012. As a result of the ARDL analysis, the authors revealed that there is a N-shaped relationship between the variables. This rejects the EKC hypothesis. Lastly, Zafar et al. (2022) asserted that economic growth contributes to the corruption of environmental quality in 22 top remittance-receiving countries over the period 1986–2017. Azomahou et al. (2006) explore the question of the existence of an EKC using a nonparametric approach in their study. In this framework they modelled the relationship between carbon dioxide (CO_2) emissions and GDP per capita. The dataset used is a balanced panel of 100 countries and it covers the period 1960–1996.

They first addressed the structural stability of the relationship between CO_2 emissions and GDP per capita and found evidence of the structural stability of the relationship over the period 1960–1996. As a result of the study the authors revealed that economic development is not a sufficient condition to reduce CO_2 emissions.

Second category studies support the validity of EKC hypothesis. Hassan, Zaman et al. (2015) investigated short and long-run carbon emissions in relation to economic growth, poverty and income inequality in Pakistan over the period 1980–2011 by using multivariate cointegration approach. They found that there is a significant negative relationship between growth and carbon emissions and economic growth and poverty while there is a positive nexus between growth and income inequality in the short-run. The results of EKC hypothesis showed an inverted U-shaped trajectory in relation to economic growth in Pakistan. Prasetyanto and Sari (2021) employed the Error Correction Model (ECM), Engel, and Granger estimating approaches to investigate the relationship between environmental degradation and economic growth in Indonesia from 1994 to 2018. They asserted that the EKC was proven both in the short and long term. Using the ARDL technique Genç et al. (2021) investigated the short- and long-run dynamic impacts of output variation on CO_2 emissions in Turkey from 1980 to 2015. In the study it is concluded that economic growth increases carbon emissions in the long run but fluctuation in output reduces carbon emissions. In addition they found that the EKC is valid for Turkey.

The third category consists of studies that reveal mixed findings regarding the CO_2 emission-growth relationship. For example, when Rasli et al. (2018) used CO_2 as an environmental pollution indicator in their investigation they found that EKC's validity was rejected for undeveloped and developing countries whereas when nitrogen oxide is taken instead of CO_2, it is positively related to GDP and the EKC is accepted.

1.2.3. Literature regarding environmental degradation-other socio-economic variables nexus

Carlsson and Lundström (2001) analyzed the effect of political and economic freedom on carbon dioxide (CO_2) emissions in their study by using the panel data analysis method for 75 country data. According to the analysis results, an increase in economic freedom reduces CO_2 emissions when the share of the public sector in the economy is low. However, economic freedoms increase CO_2 emissions when it is high.

Li and Reuveny (2006) examined the data from 134 countries from the 1980s, 1990s, and 2000s and found that democracy reduces CO_2 emissions. The relationship between democracy and environmental quality is estimated by Mak Arvin and Lew (2011) using Generalized Least Squares (GLS) data from 141 developing countries from 1976 to 2003. Their CO_2 emission results by income group show that more democracy has a positive effect on CO_2 emissions in both upper and lower-middle-income countries. Eren (2022) suggested that environmental degradation is less in countries with a high understanding of democracy.

Le et al. (2016) investigated the relationships between particulate matter emissions as an indicator of environmental degradation, openness to trade, real GDP per capita and GDP per capita squared using a panel data model with data from 98 countries for the period 1980–2013. As a consequence of the study they discovered that increased trade openness leads to environmental degradation for the worldwide sample. However, it is important to note that the outcomes vary depending on the nations' wealth levels. Trade openness benefits the environment in high-income nations while harming the environment in middle- and low-income countries. The findings support the prevalent belief that affluent countries dump their pollutants on impoverished countries.

Gulistan et al. (2020) used yearly data from 112 nations from 1995 to 2017 to examine the influence of economic development, energy consumption, trade openness and tourism on environmental degradation as measured by CO_2 emissions. For predictions, the authors employed Pooled OLS, fixed and random effects models and GLS. Further liberalization of trade in Latin America and the Caribbean, the Middle East and North Africa, and Sub-Saharan Africa has been observed to be dangerous for the environment.

Anwar, Sinha et al. (2021) investigated the effects of urbanization, renewable energy consumption, financial development, agriculture and economic growth on CO_2 emissions in 15 Asian economies between 1990 and 2014 using the Fully Corrected Least Squares (FMOLS) Method. With the analysis made in the study they concluded that urbanization, financial development and economic growth increase CO_2 emissions but that renewable energy consumption reduces CO_2 emissions and the effect of agriculture is insignificant.

Sun et al. (2022) evaluated the relationship between globalization, green innovation, renewable energy consumption, economic growth, population and carbon emissions in ten polluted countries using data from 1991 to 2018. Following the theoretical basis of the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model and using the Moment Quantile Regression (MMQR) methodology. As a result of this study globalization leads to higher emissions in all quantities (low, medium and high emission levels). Besides, green innovation mitigates carbon emissions but the mitigation effect is only significant at higher emission levels. This shows that green innovation is beneficial at high levels of environmental pollution. Similarly, renewable energy consumption is negatively and significantly correlated with carbon emissions. This means that renewable energy consumption helps to tackle the problem of carbon emissions at lower and higher pollution levels.

Recently, Bucak (2022) explored the effect of the economic freedom index of Turkey, Mexico, China, India, Brazil, Russia and Indonesia on the ecological footprint of the 2000–2017 period using panel data analysis methods. As a result of the analysis the author found that when the economic freedom index increased by 1% the ecological footprint decreased by 0.35%.

In the existing literature there are different views and conclusions regarding the impact of socio-economic variables on environmental degradation. This requires a reconsideration of the study with a different empirical methodology.

2. Data set and model

Variables were examined in the study in order to demonstrate the influence of socioeconomic factors on pollution. Studies from the current literature were used to help determine them. While the presence of more studies in the related literature provides an advantage in the selection of variables it may pose a risk in terms of the originality of the study. In order to extend the previous literature, both the number of variables have been increased and the hypotheses have been tested with different and more up-to-date methods. In this regard the study's data were chosen for the period 1995–2019 from 62 countries with the majority of the data coming from poor and middle-income countries and only with a tiny portion coming from recently high-income countries. It is also noteworthy that the country set is as large and contains as many different countries as possible within the selected period in terms of the sound results of the study. One of the most important reasons for selecting low-income country groups is to examine the relationships of these variables with pollution. In contrast their efforts to converge with developed countries for welfare increase and some of these efforts are based on economic liberalism, democracy and economic freedoms as a representative of institutional change. Today as the driving force of economic development it is suggested that underdeveloped and developing countries also implement the policies implemented by developed countries. Especially low-income countries were included in the model due to the desire to investigate the pollution effects of the policies implemented by underdeveloped and developing countries. Countries included in the model are those whose data can be accessed on a sound basis. Low- and middle-income countries whose data are available are also included in the model. On the other hand relatively high-income countries were also included in the model in order to investigate the effects of welfare increase and pollution at different levels in the model. The aim here is to both examine the relationships between variables at different quantile levels by providing an econometric advantage and to support the claims made by creating a model from different country groups. However, there are some factors that limit the period range obtained for the data such as the excessive number of variables to be used in the data set, the limitations in obtaining the data and the unavailability of data for some countries. Benefitting from the extant literature, total carbon emissions of countries, income level per capita with fixed prices in 2015, squared income per capita, cubic income per capita, average schooling rate, trade openness, average life expectancy, democracy and economic freedom index were determined as the variables used. While variables such as per capita income, development of economic freedoms and average life expectancy among the variables used in the model reveal the welfare and health-based effects of economic development, instruments such as schooling and the development of democracy reflect the effects of social and social development. The income per capita also includes characteristics such as the rate of urbanization which increases with income, and energy consumption which increases appropriately. The variables stated above are not included in the model to prevent the possibility of multiple connections. Per capita income illustrates the evolution of urbanization with rising energy consumption and it has taken on the function of indirectly reflecting economic, social and health trends.

As stated in the introduction firstly, the relationship between income per capita and carbon emission at different quantile levels will vary depending on the low and high carbon emissions. The validity of the Environmental Kuznets Curve depending on the direction of these relationships will be investigated. In the next phase the relationship between trade openness, mean schooling and life expectancy at birth with carbon emissions will be investigated. The next stage will investigate democracy and economic freedom index and pollution relationships as representatives of economic and social freedoms and the direction of these relationships will be investigated. The aim is to reveal the effects of the variables that play a role in the economic development process on pollution in the group of heterogeneous countries with different pollution levels and different economic development levels. The databases from which the variables used in the model are obtained and the abbreviations to be used in Table A1 (see Appendix 1).

One of the variables—carbon emission—reflects the total emission levels of the countries included in the model. The GDPPC income level is based on 2015 constant prices. The mean schooling rate was obtained from United Nations Development Program data (Alkhateeb et al., 2020; Scheidt, 2019), Trade Openness—the ratio of countries' foreign trade to their national income (Eren, 2022; Gulistan et al., 2020)—and Life Expectancy at Birth data were provided from The World Bank and Democracy (Eren, 2022; Li & Reuveny, 2006) was obtained from the Freedom House database. Freedom House evaluates the civil liberties of citizens living in countries and the development process for the protection of property rights with a score of 1–7. While the highest level of democracy is indicated for the countries with 1 point, it is stated that the countries with 7 points have the lowest democracy and an enthusiastic authoritarian management approach. In this context, evaluations of the effects of democracy and authoritarian structures on the level of pollution may make the study even more important. The natural logarithms of the variables used in the study were taken (Alshehry & Belloumi, 2016; Bunnag, 2023; Harbaugh et al., 2002; Ojaghlou et al., 2023; Shafik & Bandyopadhyay, 1992; Shahbaz et al., 2014; Terrell, 2020) However, it has been determined that the democracy is calculated as one point for some countries in the model. For the natural logarithmic values in the model not to be negative a method frequently used in the literature was applied and the following arrangement was made for the democracy variable in the model (Busse & Hefeker, 2007; Odugbesan et al., 2021):

$$y = \ln\left(x + \sqrt{(x^2 + 1)}\right)$$

By employing formation the problem of obtaining negative values of democracy data was solved and the research model was created. In the light of the above information the research hypotheses are as follows:

H1: There is an "inverted N" relationship between per capita income level and pollution.

H2: There is a positive relationship between mean schooling and pollution.

H3: There is a negative relationship between trade openness and pollution.

H4: There is a positive relationship between life expectancy at birth and pollution.

H5: There is a positive relationship between the coefficient of democracy and pollution.

The fact that the number of nations is more than the number of years while developing the model allows for the use of several estimating methods in the model. Estimation tests to be used depending on the validity of the primary test reveal the effects of socioeconomic-based variables on the pollution determination process in low and middle-income country groups and will support these countries in the policies that they will develop in the fight against pollution. In terms of verifying the hypotheses the increase in the variety of prediction tests to be applied to the model has particular importance in terms of the study's originality and contribution to the literature. On the other hand testing the primary research questions of the study with different estimation tests is one of the study's strengths.

Quantile regression is used to investigate the differential distribution effects of some different socioeconomic factors on pollution (Sini et al., 2022). While quantile regression represents the dependent variable's conditional distribution (Koenker & Bassett, 1978) it may also offer a comprehensive output of the factors influencing the dependent variable (Eren, 2022). One of the critical advantages of quantile regression is that it is resistant to problems such as heteroscedasticity and cross-section dependence (Koenker & Hallock, 2001). Quantile regression can also resist outlier and non-normal distributions (Zhu, Duan et al., 2016). However, quantile regression does not include the unobserved heterogeneity of a country in the model. Many studies in the literature use the quantile regression approach with panel data. Especially recently some studies control the individual heterogeneity that has not been observed with different quantile levels and thus make it possible to predict the conditional heterogeneous covariance effects of dependent variable factors (Chen & Lei, 2018). One of the essential advantages of the quantile regression used in the estimation process is that it provides the opportunity to evaluate the relationship between pollution and socioeconomic factors much more soundly in countries with different economic structures. In countries with different quantile ranges the effects of variables may be different which is another advantage of quantile regression which provides estimation in heterogeneous panels. The fact that quantile regression creates variable results in countries with different pollution levels will also contribute to the economic development processes of country groups by providing an advantage in policy proposals to be formed for country groups. The conditional quantile for x_i of y_i to be created for the carbon emission model can be expressed as follows:

$$Q_{y_{it}}(\tau \mid x_{it}) = x_{it}^{\tau}\beta_{\tau}$$

$Q_{y_{it}}(\tau \mid x_{it})$ stands for τ quantile of the dependent variable. x_{it}^{τ} τ shows the vector of explanatory variables for country i in year t for quantile (Wu et al., 2018).

In the empirical parts of the study the descriptive statistics of the variables, cross-section dependency tests, multicollinearity tests, first and second-generation unit root tests, quantile regression estimation tests and calculation results of turning points were evaluated.

Based on the above expressions the model of the study for quantile regression is:

$$\begin{aligned} Q_{\tau}(CO_{2it}) = \alpha_{\tau} + \beta_{1\tau}GDPPC_{it} + \beta_{2\tau}GDPPC_{it}^{2} + \beta_{3\tau}GDPPC_{it}^{3} + \beta_{4\tau}School_{it} + \\ + \beta_{5\tau}Trade_{it} + \beta_{6\tau}Life_{it} + \beta_{7\tau}Democracy_{it} + \beta_{8\tau}Economic\,Fredom_{it} + \mu_{it} \end{aligned}$$

"CO_2" total carbon emissions, "GDPPC" per capita income, "$GDPPC^2$"per capita income squared, "$GDPPC^3$" per capita income cubed, "School" average schooling, "Trade" trade openness, "Life" life expectancy at birth, "Democracy" democracy coefficient, "Economic Freedom" index of economic freedom, "μ_{it}" represents the error term of the model. $\beta_{1\tau}$ indicates the parameter of the variable in the τ quantile.

For the research to validate the EKC hypothesis the turning points for a cubic model were calculated. For the EKC hypothesis to be valid in the quadratic models the coefficients of the variables are expected to be "$\beta_1 > 0$", "$\beta_2 < 0$" at the calculated turning points but conversely the turning point can also be calculated. Although the calculations used to test the validity of the Environmental Kuznets Curve are generally quadratic calculations are made using cubic models in recent studies. Accordingly calculating the turning points in the EKC model as a quadratic version based on quantile regression is shown below:

$$PEAKCO2_{\tau} = -\frac{\beta_{1\tau}}{2\beta_{2\tau}}$$

The EKC process is valid when the milestones contain the result $\beta_1 > 0$, $\beta_2 < 0$ (Dinda, 2004; Stern, 2004).

As used in the study when an estimator such as "β_3" is added to the analysis the turning points calculation for the cubic version of the model is shown below. Here the coefficients β_1, β_2 and β_3 are interpreted together when calculating the turning points. When the coefficients are significant turning points can be calculated in cases where an N or an inverse N-shaped relationship occurs (AlKhars, et al., 2022):

$$PEAKCO2\beta_1 = \frac{-\beta_{2\tau} - \sqrt{\beta_{2\tau}^2 - 3\beta_{1\tau}\beta_{3\tau}}}{3\beta_{3\tau}}$$

$$PEAKCO2\beta_2 = \frac{-\beta_2 + \sqrt{\beta_2^2 - 3\beta_1\beta_3}}{3\beta_3}$$

3. Findings

The information obtained about the basic tests and the study's estimation results are included in this section. The descriptive statistics of the study are given in Table A2 (see Appendix 1).

Descriptive statistics values for the series were created from natural values of the variables. The variables have 1,550 observations in total. In addition, all variables in the Jarque-Bera test has statistically significant results at 1%. This illustrates that the series is not normally distributed. It is an expected result that the series are not normally distributed because there are countries with different economic structures and sizes in the model. The coexistence of a heterogeneous group of low, middle and high income countries will cause the series not to be normally distributed as expected. In this case the quantile regression estimator to be used for the estimation of the relationships between the series will be advantageous in testing the claims unlike OLS. Table A3 (Appendix 1) shows the correlation matrix results of the series.

According to the results in Table A3 the correlations between the other variables are less than 0.70 indicating that there is no multicollinearity problem among the series. Apart from this there are moderate correlations between life expectancy and GDPPC income, economic freedom and GDPPC income. However, since the correlation levels are less than 0.70 it does not pose a risk for the model. In the continuation of the study the multicollinearity problem which reflects the correlation relationships between the variables will be investigated. VIF (Variance Inflation Factor) test results are given in Table A4 (see Appendix 1).

According to the VIF test results the mean VIF value of the model was calculated as 1.47. While the mean VIF value is higher than five points to the multicollinearity problem (Menard, 1995; O'Brien, 2007), the general idea in the literature is that the average VIF value up to ten in the models to be created is a problem (Kennedy, 1992; Marquardt 1970; Mason et al., 1989). The VIF test does not include the model's square of GDPPC since it will directly cause multicollinearity. According to the test findings the model has no multicollinearity issues. Table A5 (see Appendix 1) shows the study's cross-section dependence test findings.

The results of the CD test proposed by Pesaran for cross-section dependence also explain the strength of the cross-sectional relationship to be found in the series. Statistically significant results of the CD test show strong cross-section dependence in the series. CD cross-section dependence tests developed by Pesaran are powerful tests, but they are also suitable for cases where $N > T$. However, in cases where $N > T$, using the LM test can also create pitfalls (Pesaran, 2020).

According to Table A5, the H0 hypothesis claims that there is no cross-sectional dependence between the series. Thus, H0 hypothesis was rejected because the p-values were less than 0.05. This result indicates that there is a cross-section dependency in the series. Finding the cross-section dependency reveals that second-generation unit root tests should be applied in the estimation process with quantile regression. The validity of second-generation unit root tests is investigated in the quantile regression estimation process. In order to better examine the unit root processes of the variables first generation unit root tests were also applied. In the literature there are studies that apply first-generation and second-generation unit root tests (Choi, 2006; Moon & Perron, 2004; Pesaran, 2007; Sini et al., 2022). Table A6 shows the results of first-generation unit root tests (see Appendix 1).

According to Table A6, carbon emission for the IPS test, GDPPC, $GDPPC^2$ and $GDPPC^3$, and the average schooling rate contain unit root at level values and the series became stationary when the first differences of all variables were taken. In the constant and trend model, the GDPPC, its forces and the average schooling rate contain unit root in level values. All variables become stationary when the first difference of the variables is taken. For the LLC test all variables are stationary at level. In the constant and trend model while GDPPC and its forces, democracy and economic freedom index contain unit root in level values all variables become stationary when the first differences of the variables are taken. The CIPS test developed by Pesaran (2007) is used for the second-generation unit root tests that should be applied in cases where cross-section dependency is valid. The results of the second-generation unit root tests for the series are given in Table A7 (see Appendix 1).

According to the results in Table A7 when the first differences of the constant and trend unit root statistics of all variables were taken it was observed that they became stationary at 1%. CIPS unit root test results for the series were obtained from Pesaran (2007). Accordingly since the series become stationary at the same level it is suitable for quantile regression estimation (Anwar, Siddique et al., 2021; Awan et al., 2022; Bui et al., 2021; Syed et al., 2022). The quantile regression estimation results for the series are given in Table 1. While the GDPPC level had a negative impact on carbon emissions the effect was positive again in the $GDPPC^2$ and negative for the $GDPPC^3$. It is not possible to mention a significant relationship only for the q20 quantile level from the series. In this case it can be stated that a relationship in the form of "inverted N or oblique S" emerged as Dinda (2004) revealed in his study. While the GDPPC level has significant results for each level of underdeveloped, developing and some developed country groups it does not support the Kuznets curve hypothesis which reveals the pollution-producing effect of welfare increase. However, the increase in GDPPC due to increasing urbanization and energy consumption may have increased pollution and caused the Environmental Kuznets Curve process to fail. Mean schooling which allows the relationship between education and pollution to be tested has significant results at the quantile level and has a positive effect. Thus, q50, q60, q70, and q80 quantile levels have a statistically positive effect at the 1% significance level while it does not have a statistically significant effect at q10, q20, q30, and q40 quantile levels. Accordingly, while schooling has an increasing effect on pollution in countries with high pollution levels it has no statistically significant effect on pollution in countries with low pollution levels. In countries where the level of pollution is high carbon emissions may increase due to both the emissions from school construction and the increase in energy consumption after school construction. However, carbon emissions may increase using primary energy sources such as increasing schooling, building construction and heating especially in countries with high pollution levels. The point to be considered here is to prioritize the long-term effects of education on pollution. In societies with high pollution levels raising educated individuals in the long term may lead to increased demands for reduced pollution in those societies. Another important variable for the model is trade openness and the effect of trade openness on pollution is negative. Trade openness negatively affects carbon emissions at a 1% statistical significance level at all quantile levels. Commercial activities have created a pollution-reducing effect for each country where the pollution level is low, medium, and high. The effect of life expectancy at birth which is an essential representative of welfare increase for societies on carbon emissions is statistically significant and positive at the 1% level for q10, q30, q40, q50, q70, and q80 quantile levels. The results of the relationship between democracy and pollution have statistically significant and positive results at the 1% level for all quantile levels. Countries with a low democracy coefficient have a higher level of democracy. Accordingly, a higher coefficient of democracy (less democracy) means more pollution since an increase in the coefficient of democracy will mean less democracy. Consequently, in countries with different pollution levels development of democracy, depending on the awareness and the development of democratic rights and freedoms in societies, leads to pollution-reducing processes in all country groups. The emergence of this situation is possible with effects such as the increase in democratic activities, development of civil freedom, development of democratic institutions and protection of rights. The relationhips s between the index of economic freedom and pollution also have similar results as h democracy. The effect of the economic freedom index which is a mixture of different levels of economic freedom, on carbon emissions is statistically significant and negative at 1% in all quantiles except for the q30 quantile level and statistically at the 10% level at the q90 quantile level. In many countries with different pollution levels as economic freedoms increase carbon emissions decrease and societies' desire to live in a cleaner world increases depending on economic freedom. In the model turning points calculated for OLS and different quantiles are given in Table 2. The approximate values of the turning points calculated in dollars and available in the table. The first and second turning points in terms of per capita income of high pollution countries are closer to each other than the first and second turning points in terms of per capita income of countries with low and medium pollution levels. This situation indicates that the intensive energy use, economic growth and development processes are operating rapidly depending on the pollution and development levels of the countries and that the production activities that cause pollution continue. While different results are calculated for different quantile levels in the calculations for model tests the results obtained using OLS estimator also differ. It is possible to mention the effects of countries having different economic structures and sizes. Moreover, the fact that the quantile regression estimation, which considers different pollution groups in various categories, contains different results at different quantile levels supports the claim. Figure 1 and Figure 2 show the visual outputs of the variables.

Table 1. Quantile regression estimation results

Variables	OLS	(1) q10	(2) q20	(3) q30	(4) q40	(5) q50	(6) q60	(7) q70	(8) q80	(9) q90
GDPPC	−105.919*** (16.60)	−50.34* (27.63)	60.41 (49.04)	−68.66** (34.19)	−79.55*** (22.26)	−123.4*** (19.40)	−142.2*** (19.13)	−124.7*** (20.10)	−131.0*** (22.03)	−77.40*** (28.57)
$GDPPC^2$	12.523*** (1.981)	5.905* (3.279)	−7.193 (5.765)	8.130** (4.018)	9.206*** (2.668)	14.46*** (2.348)	16.68*** (2.295)	14.67*** (2.416)	15.48*** (2.624)	9.310*** (3.326)
$GDPPC^3$	−0.488*** (0.0783)	−0.225* (0.129)	0.289 (0.225)	−0.315** (0.157)	−0.348*** (0.106)	−0.557*** (0.0938)	−0.644*** (0.0909)	−0.569*** (0.0959)	−0.604*** (0.104)	−0.369*** (0.129)
School	0.423*** (0.114)	−0.159 (0.166)	−0.297 (0.289)	0.0851 (0.191)	0.347 (0.257)	0.586** (0.298)	0.886*** (0.318)	1.196*** (0.387)	1.315*** (0.403)	0.446 (0.929)
Trade	−1.531*** (0.0954)	−1.841*** (0.151)	−1.763*** (0.218)	−1.409*** (0.100)	−1.531*** (0.125)	−1.493*** (0.135)	−1.539*** (0.149)	−1.570*** (0.193)	−1.190*** (0.247)	−1.159*** (0.254)
Life	3.963*** (0.500)	6.305*** (0.859)	1.363 (2.201)	3.816*** (0.509)	3.885*** (0.471)	3.925*** (0.408)	4.034*** (0.488)	4.789*** (0.598)	6.384*** (1.655)	0.195 (1.623)
Democ	0.654*** (0.0550)	0.934*** (0.104)	0.714*** (0.138)	0.821*** (0.107)	0.664*** (0.0770)	0.610*** (0.0503)	0.644*** (0.0466)	0.669*** (0.0658)	0.696*** (0.0853)	0.412*** (0.137)
Freedom	−2.900*** (0.349)	−2.005*** (0.489)	−1.596 (1.158)	−2.559*** (0.404)	−3.244*** (0.320)	−3.515*** (0.278)	−3.333*** (0.389)	−3.200*** (0.689)	−3.527*** (0.881)	−2.665* (1.414)
Constant	227.3*** (40.07)	142.0* (74.08)	−149.6 (129.6)	204.2** (96.03)	242.7*** (61.38)	364.4*** (53.04)	416.3*** (53.24)	362.6*** (55.58)	372.4*** (59.54)	244.5*** (82.49)
Turning point	7.648 (1) 9.459(2)	7.233 (1) 9.340 (2)	– –	7.030 (1) 9.767 (2)	7.334 (1) 10.299 (2)	7.611 (1) 9.700 (2)	7.640 (1) 9.648 (2)	7.642 (1) 9.577 (2)	7.662 (1) 9.450 (2)	7.429 (1) 9.436 (2)
Obs.	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,550	1,550

Notes: ***, **, * indicate 1%, 5% and 10% significance levels, respectively. (1) is the 1st Turning point, and (2) is the 2nd Turning point

Source: based on Stata 14.

Table 2. The approximately calculated turning points of quantile levels

Quantile level	1st Turning point	2nd Turning point
Q10	1385$	11385$
Q20	–	–
Q30	1131$	17360$
Q40	1532$	29730$
Q50	2022$	16330$
Q60	2080$	15500$
Q70	2085$	14440$
Q80	2127$	12715$
Q90	1685$	i12543$
OLS	2097$	12825$

Source: based on Stata 14.

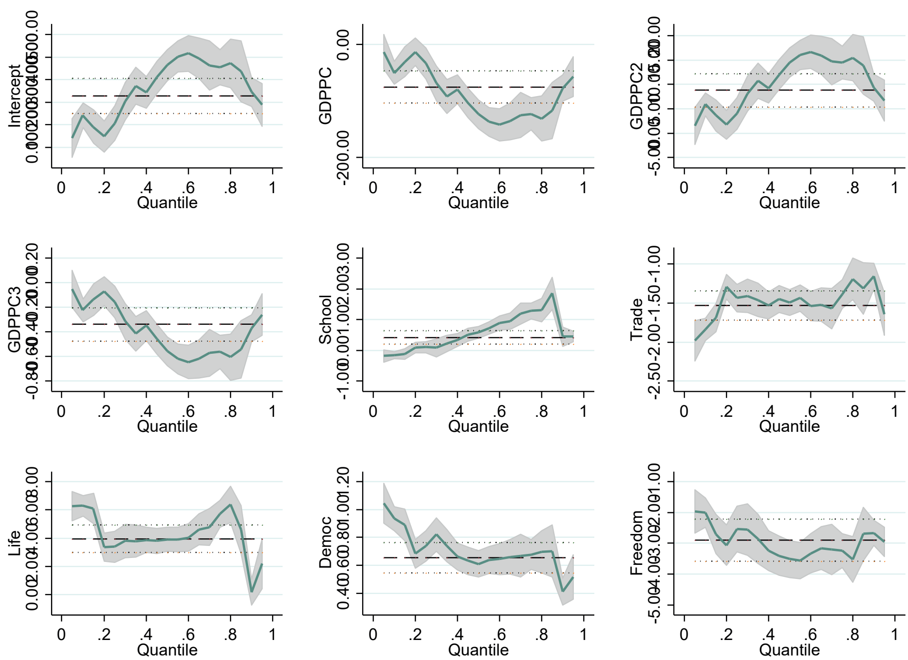

Figure 1. Quantile output

Source: own work.

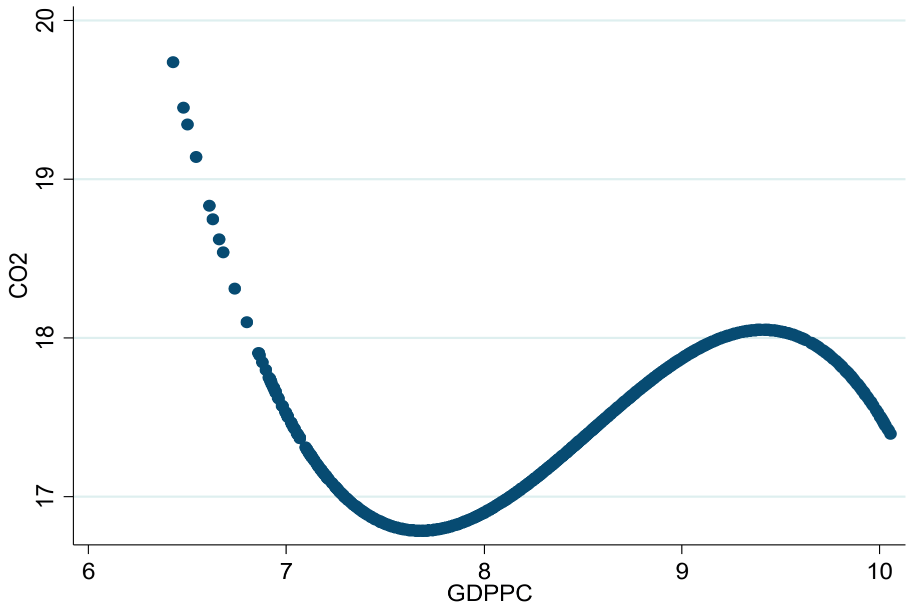

Figure 2. OLS output

Source: own work.

4. Discussion

This study investigated 62 countries with available data from low and middle-income countries from 1995–2019. In order to extend the previous literature the number of variables has been increased, and so by making use of the literature; Variables used as GDPPC, $GDPPC^2$ and $GDPPC^3$, average schooling rate, trade openness, average life expectancy, democracy and economic freedom index were determined with 2015 prices. However, since the ecological footprint and carbon emission are the most widely used indicators of environmental degradation in the literature carbon emission was used as the dependent variable in this study. The main purpose here is to reveal the relationship between environmental pollution and welfare increase and some other socioeconomic variables. Quantile regression estimation allows the investigation of changes in different country categories.

As a result of the quantile regression analysis it was found that the The EKC process is not valid for low-income and middle-income countries in analyzing the relationship between economic growth and carbon emissions. Instead, as Dinda (2004) revealed in his study it can be stated that there is an *inverted N or oblique S* relationship. The findings do not support the Kuznets curve hypothesis which reveals the pollution-producing effect of welfare increase. This also confirms Schor's (1998)'s thought by not supporting Kuznets's inverted U hypothesis. It can be stated that is caused by the different economic structures of the country groups in the model and the polluting lifestyle caused by the production process that creates the pollution and a lack of environmental awareness. An unfair income distribution and higher working hours support the expression of a polluting lifestyle and emissions. The increase in GDPPC due to increasing urbanization and energy consumption may have increased pollution and caused the Environmental Kuznets Curve process to fail (Aye, 2020; Fitzgerald et al., 2015; Knight et al., 2013).

It has been revealed that the schooling rate has a pollution-increasing effect. While schooling has an increasing effect on pollution in countries with high pollution levels there is no statistically significant effect of the increase in average schooling in countries with low pollution levels. Education and schooling processes can increase carbon emissions in the first place with increased emissions based on energy (Romuald, 2010; Scheidt, 2019). The long-term effects of education on pollution is important. Increasing the level of education will lead to the training of educated individuals who demand pollution-reducing policies in the long term and take part in the production process to reduce pollution. However, according to the results carbon emissions may increase though the use of primary energy sources such as increasing schooling, building construction and heating, especially in countries with high pollution levels. The long-term effect of education on reducing pollution should be considered (Eyuboğlu & Uzar, 2021; Fotourehchi, 2017; Hassan, Batool et al., 2022; Khan, 2020; Zhu, Peng et al., 2021). The effect of the trade openness variable on reducing environmental degradation was observed. Trade has created a pollution-reducing effect for quantile groups that have low, medium and high pollution levels. The findings partially agree with Carlsson and Lundström's (2001) results. While pollution decreases with the increase in economic freedom and the decrease in the public sector the increase in trade openness can be evaluated as supporting the development of the private sector in an economy. While trade openness is closely related to economic freedom the decrease in emissions will also create a result in line with the literature. Considering that the pollution-reducing effect of trade openness is made with developed countries which have a heavy weight in world trade it also shows that environmental awareness has developed in high income countries. Just as trade openness the economic freedom variable has a reducing effect on environmental degradation (Bucak, 2022). In many countries with different pollution levels and as economic freedoms increase carbon emissions decrease and societies' desire to live in a cleaner world increases depending on economic freedom. Depending on the economic development processes associated with democracy and freedoms the pollution behaviour did not show the Environmental Kuznets Curve behaviour for the GDPPC and $GDPPC^2$.

It was observed that life expectancy at birth has an increasing effect on environmental degradation. The increase in life expectancy at birth has a pollution-increasing effect in countries with low, medium and high pollution levels.

Democracy reduces the environmental degradation. Depending on the development of democratic rights and freedoms in societies, social awareness at every pollution level and democracy based on this awareness leads to pollution-reducing processes in all country groups. The results support the claim that a greater level of democracy will reduce pollution. (Eren, 2022). In countries with a high level of education and high social consciousness the pollution-reducing effect of democracy will make it possible to create a cleaner and more livable world.

Conclusions and limitations

The study reveals that the Kuznets inverted U relationship is not valid and that the threshold pollution levels vary according to different income groups and so environmental policies should be handled more carefully in terms of different country groups. Reductions in long-term environmental degradation dynamics in societies with higher welfare, improved democracy and raising healthy individuals give us hope for a better future. At the same time the fact that the Kuznets model is not valid reveals that countries should be more sensitive to environmental protection and develop more protective policies.

High economic freedom and trade openness supporting democratically inclusive policies will help low and middle-income countries reach income thresholds where pollution will begin to decrease. Supporting policies that are more open to the outside supportive of economic freedom and inclusive of the society in a democratic sense will provide advantages in reducing pollution for groups of countries with moderate pollution to reach their income thresholds. As a matter of fact, the findings of the studies in the literature are in line with these claims. Higher incomes, lower pollution and healthier people are desirable for the whole world.

One of the important limitations of the study is the problems in obtaining data for different country groups. The increase in the number of variables used in the model can also cause problems in the estimation process such as multicollinearity.

Appendix 1

Table A1. Information on abbreviations of variables used in the model and the platforms from which they are obtained

Variable	Abbreviation	Database
Carbon Emissions	CO_2	OurWorldinData
GDP per capita	GDP	The World Bank
GDP per capita^2	GDP^2	The World Bank
GDP per capita^3	GDP^3	The World Bank
Economic Freedom	Freedom	Heritage.org
Mean Schooling	School	UNDP
Trade Openness	Trade	The World Bank
Life Expectancy At Birth	Life	The World Bank
Democracy	Democ	Freedom House

Source: authors' compilation.

Table A2. Descriptive statistics

	Mean	Min.	Max.	Standard deviation	Median	Skewness	Kurtosis	Jarque-Bera	Obs
CO_2 (kt)	2.55e+08	307776	1.05e+10	9.61e+08	3.11e+07	7.979879	73.91534	3.4e+05***	1550
GDP ($)	6370.837	618.367	23243.59	4871.841	4806.924	1.372979	4.452948	623.3***	1550
GDP^2 ($)	6.43e+07	382378.7	5.40e+08	9.92e+07	2.31e+07	2.560249	9.634104	4536***	1550
GDP^3 ($)	8.71e+11	2.36e+08	1.26e+13	1.98e+12	1.11e+11	3.47436	15.66441	1.3e+04***	1550
School (Years)	14.12155	2.5	13.143	2.322439	8.326	–0.102124	2.290984	35.16***	1550
Trade (%)	80.65387	15.63559	220.4068	35.33266	75.93649	0.739264	3.318283	147.7***	1550
Life (Years)	70.58271	49.475	81.67561	6.208346	72.0505	–1.365748	4.780265	686.5***	1550
Democ (1–7)	3.359355	1	7	1.528899	3	0.3331289	2.245312	65.45***	1550
Freedom (1–100)	60.50765	26	79.1	7.943645	61.05	–0.360895	3.410326	44.52***	1550

Notes: ***, **, * indicate 1%, 5% and 10% significance levels, respectively.

Source: authors' computation.

Table A3. Correlation matrix

	CO_2	GDPPC	$GDPPC^2$	$GDPPC^3$	School	Trade	Life	Democ	Free.
CO_2	1.0000								
GDPPC	0.1583	1.0000							
$GDPPC^2$	0.1616	0.9986	1.0000						
$GDPPC^3$	0.1637	0.9945	0.9986	1.0000					
School	0.0677	0.4349	0.4299	0.4237	1.0000				
Trade	–0.3896	0.2073	0.2057	0.2046	0.2753	1.0000			
Life	0.2071	0.5457	0.5412	0.5355	0.3229	0.1248	1.0000		
Democ	0.2276	–0.3967	–0.3986	–0.3988	–0.2929	–0.1830	–0.2278	1.0000	
Free	–0.2257	0.4834	0.4843	0.4842	0.1515	0.2835	0.2673	–0.4242	1.0000

Source: authors' computation.

Table A4. VIF test results

Variable	VIF	1/VIF
GDPPC	1.97	0.506996
Freedom	1.52	0.657481
Life	1.44	0.692866
School	1.37	0.731953
Democ	1.34	0.748261
Trade	1.16	0.863661
Mean VIF	1.47	

Source: authors' computation.

Table A5. Cross-section dependency test results

Variable	CD Test Value	Breusch-Pagan LM	Pesaran Scaled LM
CO_2	76.11410***	24513.16***	367.8522***
GDPPC	166.0553***	35683.80***	549.4946***
$GDPPC^2$	166.0991***	35665.90***	549.2035***
$GDPPC^3$	166.1227***	35640.46***	548.7899***
School	186.8187***	37389.71***	577.2339***
Trade	35.27508***	10710.03***	143.4036***
Life	196.4874***	40175.90***	622.5393***
Democ	114.4694***	21331.52***	316.1165***
Freedom	17.42966***	11119.50***	150.0619***

Notes: ***, **, * indicate 1%, 5% and 10% significance levels, respectively.

Source: authors' computation.

Table A6. First-generation unit root test results

IPS (Im, Pesaran, Shin)				
Variable	Constant		Constant + Trend	
	I(0)	I(1)	I(0)	I(1)
CO_2	1.59022	–18.4262***	–2.00905**	–14.9675***
GDPPC	5.80641	–10.9650***	0.37622	–8.58117***
$GDPPC^2$	6.40456	–10.9268***	0.27607	–8.47881***
$GDPPC^3$	6.99475	–10.8646***	0.20112	–8.38305***
School	–0.13622	–10.6024***	0.49504	–7.10151***
Trade	–2.86532***	–18.5330***	–2.02672**	–14.9766***
Life	–6.84924***	–23.5411***	–32.6418***	–40.3476***
Democ	–2.9E+13***	–13.6757***	–2.5E+13***	–10.9466***
Freedom	–3.67870***	–17.2880***	–1.44284*	–13.9498***

Notes: ***, **, * indicate 1%, 5% and 10% significance levels, respectively.

LLC (Levin, Lin, Chu)				
Variable	Constant		Constant + Trend	
	I(0)	I(1)	I(0)	I(1)
CO_2	–3.14855***	–14.2626***	–2.95555***	–10.6819***
GDPPC	–2.30656**	–10.3765***	–1.27643	–10.5966***
$GDPPC^2$	–1.58475*	–10.4652***	–1.36034	–10.0993***
$GDPPC^3$	–1.56480*	–10.4791***	–1.48481	–9.92887***
Energy	–2.80766***	–12.2750***	–1.13741	–9.07933***
School	–8.25518***	–8.53357***	–2.54147***	–6.23002***
Trade	–4.23463***	–17.2918***	–2.02443**	–13.8723***
Life	–10.8429***	–27.3169***	–49.2866***	–31.2176***
Democ	–3.55885***	–3.59009***	0.91486	–8.59385***
Freedom	–3.92822***	–12.4700***	–0.70003	–9.87813***

Notes: ***, **, * indicate 1%, 5% and 10% significance levels, respectively.

Source: authors' computation.

Table A7. Second-generation unit root test results

CIPS Test			
Variable	Constant&Trend		
	I(0)		I(1)
CO_2	–2.638*		–4.960***
GDPPC	–1.715		–3.394***
$GDPPC^2$	–1.662		–3.364***
$GDPPC^3$	–1.641		–3.333***
School	–1.877		–3.690***
Trade	–2.604*		–4.362***
Life	–2.299		–4.061***
Democ	–2.214		–3.759**
Free	–2.560		–5.046***
Critic	10%	5%	1%
Values	–2.58	–2.65	–2.78

Notes: ***, **, * indicate 1%, 5% and 10% significance levels, respectively. Constant and trended values of the series are used.

Source: authors' computation.

Appendix 2

List of countries

Albania
Algeria
Argentina
Armenia
Azerbaijan
Bulgaria
Bahrain
Belarus
Belize
Bolivia
Brazil
Botswana
Cameroon
Chile
China
Cote d'Ivoire
Colombia
Costa Rica
Croatia
Czech Republic
Dominic Republic
Ecuador

Egypt
Estonia
Fiji
Gabon
Ghana
Guatemala
Honduras
Hungary
Indonesia
India
Jamaica
Jordan
Kazakhystan
Lithuania
Latvia
Morocco
Moldova
Mexico
Mongolia
Malaysia
Namibia
Nicaragua
Pakistan
Panama
Peru
Phillipines
Poland
Portugal
Paraguay
Romania
Russia
Saudi Arabia
El Salvador
Thailand
Tunisia
Turkey
Ukraine
Uruguay
South Africa

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