# $CO_2$ Emissions-Economic Growth Relationship Revisited: New Insights from the Time-Varying Cointegration Approach

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***Abstract***

One of the most discussed topics of Environmental economics is the choice of the appropriate functional form to examine the income-environmental impact relationship. Since the developing economies encounter different development stages, the use of relevant specification and technique gains special importance to reveal the country specific relationship. Considering the afore-mentioned points, this study employs the time-varying cointegration approach to investigate the $CO_2$ emissions-economic growth relationship in the case of developing country, Azerbaijan. Time-varying cointegration approach a) takes into account the varying nature of elasticity of emissions and b) does not require the functional specification to be a polynomial. The results document a long-run relationship between carbon emissions and income. The study also concludes that the EKC hypothesis does not hold in Azerbaijan. The positive and time-varying income elasticity of carbon emissions, slightly decreasing at the end of the time period, can be seen as an indication that the country has implemented a number of successful emission/pollution regulatory measures.[4]

***Keywords***

*$CO_2$ emissions, time-varying cointegration approach, economic growth, EKC hypothesis, Azerbaijan*

***JEL code***

*C14, C32, Q01, Q43, Q52, Q53, Q56*

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## INTRODUCTION

The Environmental Kuznets Curve (EKC) framework illustrates the link between certain indicators of environmental degradation and income per capita. The main question that the EKC hypothesis places is whether the level of environmental degradation does increase or not during a country's economic growth stage. The discussion on the EKC hypothesis gained substantial momentum back in the early 1990's when Grossman and Krueger (1991) explored the potential impact of North American Free Trade Agreement (NAFTA) and the concepts of popularization in the 1992 World Bank Development Report (Stern, 2003). At the early stages of economic growth, environmental pollution rises along with a growth in national per capita income as people are more interested in jobs and income than clean air and water, which results in inadequate environmental regulation. However, at higher income levels, environmental degradation decreases as people increasingly value environmental quality along with regulation standards, implying an inverted U-shaped EKC curve. This framework can explain the path of Carbon-dioxide ($CO_2$) emissions using different order polynomial functions of income level. Many reasons can explain the spur of this relevant discussion, with the primary being the rapid climate change issue over the last few decades, as well as the problem of global warming. The EKC hypothesis has been investigated for a range of environmental indicators (see for example, Wang et al., 2013; inter alia). One of the hot topics in the environmental degradation-income literature is the choice of the appropriate functional form in relevance to the above link. The conventional form used is the polynomial function of the income variable, which has received certain criticism (Liddle and Messinis, 2016; Mikayilov et al., 2018b) in terms of representing the true response of environmental indicators to changes in the income variable. There are certain studies that have employed different methodological approaches, such as spline functions (Schmalensee, Stoker, Judson, 1998), non-linear-in-parameters specifications (Galeotti, Lanza, Pauli, 2006), Quantile Cointegration Regression approach (Apergis, 2016), a reduced form linear modeling approach (Liddle and Messinis, 2016) and a time-varying coefficient cointegration approach (Mikayilov et al., 2018b). In addition to the concerns discussed in Mikayilov et al. (2018b), the common feature of all the above-mentioned studies is that all have investigated the relationship in relevance to the case of developed countries. As it is well known, the EKC literature argues that the shape of the relationship between an environmental indicator (i.e., $CO_2$ emissions) and the income variable is mainly U-shaped in the case of developed countries, while for the developing country cases, it needs to be investigated for certain individual countries. Therefore, it is worth analyzing the relationship in the case of developing countries by employing one of the methods that explicitly considers the weaknesses of the previous studies.

Given the above discussion, the goal of this study is to empirically examine the rationality of the EKC hypothesis in the case of Azerbaijan, using time-varying cointegration methodology, for the first time, for a developing country case. This methodology provides certain advantages in the empirical analysis, such as considering the possibility that the coefficients can vary over time, taking into account the long-run relationship and testing for it. For country case, the current paper investigates that of Azerbaijan for a number of reasons: Firstly, to our knowledge, the time-varying coefficient approach has not been applied to the case of a developing economy; Azerbaijan has witnessed different economic phases, beginning with the post-Soviet period, which increases the likelihood of the drivers to respond to certain factors in a time-varying manner. Secondly, Azerbaijan is a resource-rich country with the empirical results potentially being set as an example for other resource-rich developing economies. Thirdly, there are a few studies on the $CO_2$ emissions-economic growth relationship in the case of Azerbaijan. Based on the above points, the current study investigates the $CO_2$ emissions-economic growth relationship in the Azerbaijani case by employing the time-varying coefficient cointegration approach, while investigating this relationship within the Environmental Kuznets Curve framework.

The contribution of the current study is twofold: Firstly, it employs a methodology (Park and Hahn, 1999), that addresses some limitations of previous research (for example, Liddle and Messinis, 2016;

Apergis, 2016; Moosa, 2017), to investigate the relation between environmental degradation and economic growth. Secondly, it employs the suggested methodology to the case of a developing economy, while all other studies in the relevant literature investigated the same relationship in the case of developed countries.

The structure of the paper is the following: a review of the related literature is given in Section 1. Section 2 provides the theoretical framework and methodology of the study. The employed data is described in Section 3. Sections 4 and 5 discuss empirical results and findings, respectively, while conclusion and policy implications are illustrated in the last chapter.

## 1 LITERATURE REVIEW

Table 1 summarizes both time series and panel studies in terms of sample period considered, functional forms selected, econometric methodologies employed, income elasticity and shape of the $CO_2$-income relationship found.

Only four studies are reviewed, since our main focus in this section is the time series studies for Azerbaijan. More specifically, Mikayilov et al. (2017a) explore the impact of urbanization, energy consumption and real Gross Domestic Product (GDP) on atmospheric pollution coming from automobile transportation in Azerbaijan within the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) framework, developed by Dietz and Rosa (1994, 1997). The study applies the Autoregressive Distributed Lags Bound Testing (ARDLBT) approach, proposed by Pesaran et al. (2001) and Pesaran and Shin (1999), spanning the period 1990–2014 and finds the presence of a long-run relationship among the variables. However, their analysis does not illustrate the trajectories of the variables to provide deep information on how their movement looks over time. Secondly, the study examines the impacts on pollution from automobile transportation, not on total $CO_2$. Mikayilov et al. (2017b) analyze the effects of energy consumption, real GDP and population on pollution stemming from the automobile transportation sector in Azerbaijan. Their study uses annual data, spanning the period 1990–2014 and utilizing the ARDLBT approach in the STIRPAT framework. Likewise, this study also investigates the impact of income on pollution from transport.

Mikayilov et al. (2018a) examine the $CO_2$ emissions effects of economic growth in Azerbaijan over the period 1992–2013. The paper finds positive impacts of income on carbon emissions in the long-run. This study employs the conventional polynomial specification and ends up with the linear form to be the best fit for the studied country case.

Finally, Shuai et al. (2017) conduct panel, as well as time series estimations for a sample of 164 countries (including Azerbaijan) within a quadratic functional form framework. The main drawback of this study is that it uses an Ordinary Least Squares (OLS) analysis, which yields biased estimation results when variables are cointegrated. The second concern is that the analysis makes use of a time span ranging from 1960–2011, while Azerbaijan gained its independence in 1991. This can potentially lead to a major problematic issue: if the analysis actually uses a data sample from 1960, then the estimations are potentially suffering from the measurement error problem, as the period 1960–1990 refers to the Soviet Union time, in which a centrally planned economic system was in effect. Additionally, the study suffers from the absence of any cross-sectional tests, as well as from any cross-sectional dependency test which generates biased panel unit root and cointegration tests.

In terms of the panel studies reported in Table 1, except that by Shuai et al. (2017), all the other studies present estimation results only for the entire panel under consideration and not for individual countries in the panel sample. Further, only the study by Perez-Suarez and Lopez-Menendez (2015) considers the cubic functional form, while the remaining studies restrict themselves to using either a quadratic or a linear functional form. All the panel studies, except that by Mitic et al. (2017), ignore the presence of any cross-sectional dependence across the data, although the countries included are linked to each other economically, financially and politically. Furthermore, certain studies, e.g. Erdogan and Ganiev (2016),

**Table 1** Review of the $CO_2$ studies for Azerbaijan

| Paper | Time Interval | Country (Group) | Specification | Estimation approach | Income elasticity | Relationship type |
|---|---|---|---|---|---|---|
| Apergis and Payne (2010) | 1992–2004 | CIS region* | QFF | FMOLS. Panel data | With Russia: 1.55–2.96 In GDP; without Russia: 1.37–2.54 In GDP | IUS |
| Tamazian and Rao (2010) | 1993–2004 | 24 countries* | QLF | GMM. Panel data | 0.04–1.22 In GDP | IUS |
| Stolyarova (2013) | 1960–2008 | 93 countries* | LLF | GMM. Panel data | Short-run elasticity: 0.3–0.79 | Not reported |
| Brizga et al. (2013) | 1990–2010 | Former USSR* | LLF | Index decomposition analysis and OLS. Panel data | 0.86 | US (Azerbaijan) |
| Perez-Suarez and Lopez-Menendez (2015) | 1860–2012 | 175 economies* | CLF | NLS. Time series data | Not reported | No specific pattern |
| Erdogan and Ganiev (2016) | 1992–2013 | 8 Central Asian countries* | QFF | Fixed effect and random effect. Panel data | 0.13 | IUS |
| Al-Mulali et al. (2016) | 1980–2010 | 107 economies* | QLF | DOLS. Panel data | 4.75–0.18 In GDP (panel with Azerbaijan) | IUS Panel with Azerbaijan |
| Ito (2017) | 2002–2011 | 42 economies* | LLF | GMM and PMGE. Panel data | GMM: 0.13 PMG: 0.34 | MI |
| Shuai et al. (2017) | 1960–2011 | 164 countries* | QFF | OLS. Time series and panel data | 0.04 | US |
| Mitic et al. (2017) | 1997–2014 | 17 countries* | LLF | DOLS and FMOLS. Panel data | 0.35 | MI |
| Mikayilov et al. (2017a) | 1990–2014 | Azerbaijan | LFF | ARDLBT. Time series data | 0.13 | MI |
| Mikayilov et al. (2017b) | 1990–2014 | Azerbaijan | LFF | ARDLBT. Time series data | 0.13 | MI |
| Mikayilov et al. (2018a) | 1992–2013 | Azerbaijan | CLF | VECM, ARDLBT, DOLS, FMOLS and CCR | 0.70 to 0.82 | MI |

**Abbreviations:** CIS = Commonwealth of Independent States, QFF = quadratic functional form, QLF = Quadratic functional form in logarithms, IUS = Inverted U-shaped, FMOLS = Fully Modified Ordinary Least Squares, US = U-shaped, GMM = Generalized Method of Moments, LLF = Log-linear function, CLF = cubic functional form in logarithms, ARDLBT = Autoregressive Distributed Lags Bounds Testing, DOLS = Dynamic Ordinary Least Squares, OLS = Ordinary Least Squares, PMGE = Pooled Mean Group Estimator, VECM = Vector Error Correction Method, NLS = non-linear least squares method, EIR = Emission-Income Relationship, MI = Monotonically Increasing, MD = Monotonically Decreasing, LS = L-shaped, NS = N-shaped, USSR = Union of Soviet Socialist Republics.
**Note:** * The study included Azerbaijan.
**Source:** Adopted from Mikayilov et al. (2018a)

Perez-Suarez and Lopez-Menendez (2015), Brizga et al. (2013) and Tamazian and Rao (2010) do not account for any non-stationarity and cointegration properties in relevance to the variables used. By contrast, our study addresses all the above-mentioned shortcomings that the earlier studies faced.

## 2 THEORETICAL FRAMEWORK AND METHODOLOGY

A typical model relating $CO_2$ emissions and income is an equation (in a logged or level form) with $CO_2$ emission on the left-hand side and the powers of income on the right-hand side (Shafik and Bandyopadhyay, 1992). A general typical model can be expressed as below:

$$lnCO_2 = \alpha_0 + \alpha_1 lnY + \alpha_2 ln^2 Y + \alpha_3 ln^3 Y, \tag{1}$$

where $CO_2$ is $CO_2$ emissions per capita and $Y$ denotes income per capita. $\alpha_i s$ are the coefficients to be estimated. For the given specification, the income elasticity of $CO_2$ emissions is defined as:

$$\eta = \frac{\partial CO_2}{\partial Y}\frac{Y}{CO_2} = \alpha_1 + 2\alpha_2 lnY + 3\alpha_3 ln^2 Y. \tag{2}$$

In the case that, the coefficient of the cubic term is insignificant and the analysis should drop it. Then, Formula (1) reduces to the quadratic functional form as follows:

$$lnCO_2 = \alpha_0 + \alpha_1 lnY + \alpha_2 ln^2 Y. \tag{3}$$

The income elasticity for specification (3) is defined as follows:

$$\eta = \frac{\partial CO_2}{\partial Y}\frac{Y}{CO_2} = \alpha_1 + 2\alpha_2 lnY. \tag{4}$$

Similarly, when the coefficient of the quadratic term is statistically insignificant then Formula (3) turns into:

$$lnCO_2 = \alpha_0 + \alpha_1 lnY. \tag{5}$$

In this case, the income elasticity of $CO_2$ emissions is the coefficient of the income variable in logarithmic form, namely $\alpha_1$. Since the elasticities in Formulas (2) and (4) include certain variables to make them interpretable and to give an idea about their sign and magnitude, it is preferred to calculate them at their mean value of income level. Other functional forms and appropriate elasticities are also possible (Shafik and Bandyopadhyay, 1992; Lieb, 2003; inter alia). Although Formula (1) is the widely used functional form in the pollution-income literature, certain studies provide a negative criticism on that (Zhang, 2012; Moosa, 2017; Liddle and Messinis, 2016; Mikayilov et al., 2018b; inter alia). As Mikayilov et al. (2018b) argue, the income elasticity of emissions depends on the chosen functional specification. For example, in Baek (2015), both the linear and cubic specifications are found to be significant in the Canadian case, while both the linear and quadratic specifications are found to be significant in the US case. Similarly, Jaforullah and King (2017) end up with significant quadratic and cubic specifications in both Canada and Finland cases, and with significant linear and cubic specifications in Sweden case. If the analysis calculates elasticities based on different specifications, it will potentially find different results, as well as different types of the emissions-income relationship. Even the magnitudes and the signs of these elasticities might be different (Jaforullah and King, 2017). Given the above discussion, it is concluded that the employment of the time-varying cointegration (TVC) approach is the appropriate method that avoids these above-mentioned shortcomings.

The use of the conventional functional approach described in Formulas (1)–(5) assumes that the elasticities are constant over time; however, certain studies (Haas and Schipper, 1998; Chang and Martinez-Chombo, 2003; Chang et al., 2014; Mikayilov et al., 2017c; inter alia) criticize the constant elasticity approach considering certain drivers, such as structural changes, shocks to an economy; different economic and political regimes. These studies reach the conclusion emphasizing that the conventional models are unstable to any potential structural deviations from the existing development path, generating estimates which lead to misrepresentative estimation results. In addition, according to Lucas (1976), under regime changes, the estimated parameters are likely unstable. To address this issue, Apergis (2016), Liddle and Messinis (2016), Moosa (2017), and Mikayilov et al. (2018b) study the $CO_2$ emissions-income relationship by employing different methods which consider the time-varying characteristic of income elasticity. Apergis (2016) and Moosa (2017) limit their study to the likelihood of changing the coefficients in the quadratic functional form, while the method employed by Liddle and Messinis (2016) requires the presence of a number of regimes (four of them in their case study). Moreover, all the above-mentioned studies focus on advanced economies. Mikayilov et al. (2018b) employ the Time-Varying Coefficient Cointegration (TVC) technique suggested by Park and Hahn (1999) for the case of advanced economies. This approach considers long-run elasticity as a function of a time. This function is approximated semiparametrically by polynomials and pairs of trigonometric functions. Assuming $\alpha_t$ to be varying elasticity over time, the model in (1) turns into a TVC model described as:

$$lnCO_{2\,t} = \alpha_0 + \alpha_t lnY_t + u_t\,, \tag{6}$$

where ($u_t$) is an error term. The coefficient  is assumed to be a function of time. The methodology will not be described here as the space is limited. For further details of the methodology and related tests, interested readers can refer to Park and Hahn (1999), Chang et al. (2014).

Before implementing cointegration among the variables, the analysis tests the unit root properties of the variables through the Elliott-Rothenberg-Stock (1996), Phillips-Perron (PP, Phillips and Perron, 1988), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS, Kwiatkowski et al., 1992) tests.

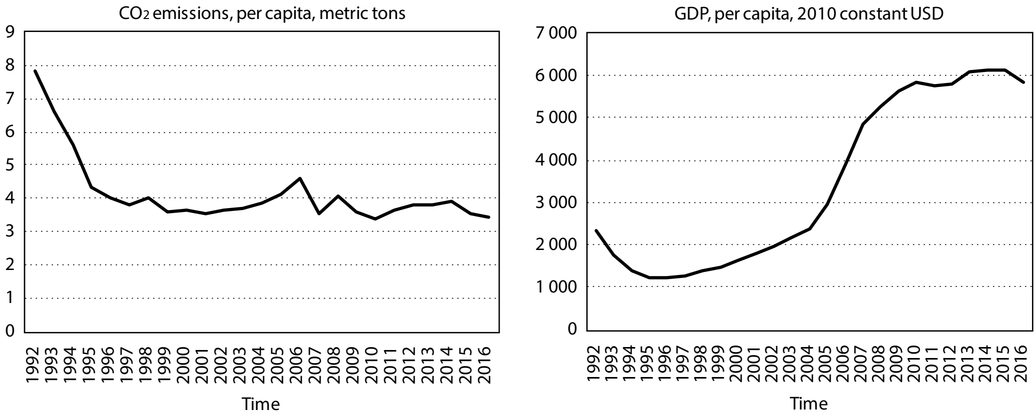
## 3 DATA

The available data ranging from 1992–2016 is used. $CO_2$ emissions ($CO_2$) are in metric tons of carbon dioxide and they are the dependent variable in the modeling approach. Data for 1992–2014 was taken from World Bank, 2015–2016 was taken from KNOEMA World Data Atlas. GDP per capita data in 2010 constant USD was obtained from the World Bank Development Indicators Database (WB, 2016). Figure 1 shows the time profile of per capita $CO_2$ and per capita GDP, over the period 1992–2016.

As it can be seen from Figure 1, GDP increases over time, while $CO_2$ emissions decreased up to 1996, then increased up to 2006, furthermore they demonstrated a volatile pattern since 2006. For the time period 1996–2016, $CO_2$ emissions in Azerbaijan increased with an annual growth rate of 3.8%, while GDP increased by 8.5% on an annual basis. The presence of a jump in 2006 might be explained by oil income coming from the completed oil projects for that time.

Descriptive statistics are given in Table 2. As it can be seen from Table 2, based on the coefficient of variation (25% for per capita $CO_2$ and 58% for per capita GDP) one can conclude that the volatility in $CO_2$ is relatively smaller and in GDP higher than 30%, which is taken in the literature as the benchmark level for a homogeneity check.

**Figure 1** Plots of the variables




**Source:** WB (2016)

**Table 2** Descriptive statistics

| Country | $CO_2$ emissions per capita, metric tons | | | | | GDP per capita, constant 2010 US$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Min | Mean | Max | St Dev | CoV (%) | Min | Mean | Max | St Dev | CoV (%) |
| Azerbaijan | 3.39 | 4.14 | 7.81 | 1.04 | 25 | 2 357 | 3 448 | 6 123 | 2 006 | 58 |

**Notes:** Min = sample minimum, Max = sample maximum, StDev = standard deviation, CoV = Coefficient of Variation.
**Source:** Authors' calculation based on WB (2016) data

The empirical analysis that follows makes use of the natural logarithm of both variables (both in per capita terms), which are denoted by small letters, i.e., $co_2$ and $y$.

## 4 EMPIRICAL RESULTS

### 4.1 Unit root tests' results

The results of the unit root tests are reported in Table 3. The overall findings illustrate that for $co_2$ emissions there is an evidence in favor of stationarity at first difference. For the case of the income variable, if only the intercept mode is considered, both the KPSS tests recommend the presence of a *I(1)* variable, while

**Table 3** Unit root tests' results

| Variable | | The ERS test | | | | The PP test | | The KPSS test | |
|---|---|---|---|---|---|---|---|---|---|
| | | Level | k | First difference | k | Level | First difference | Level | First difference |
| Intercept | $co_2$ | $-1.74^{*}$ | 0 | $-2.17^{**}$ | 1 | $-5.07^{***}$ | $-4.97^{***}$ | 0.42 | $0.34^{***}$ |
| | y | $-2.65^{**}$ | 1 | $-1.84^{*}$ | 1 | $-0.39^{*}$ | $-2.73^{*}$ | 0.63 | $0.23^{***}$ |
| Intercept and trend | $co_2$ | −2.56 | 0 | | | $-3.95^{**}$ | | $0.14^{**}$ | |
| | y | $-3.00^{*}$ | 1 | | | −3.11 | | $0.11^{**}$ | |

**Notes:** ERS, PP and KPSS denote the Elliott-Rothenberg-Stock test, Phillips-Perron and Kwiatkowski-Phillips-Schmidt-Shin tests, respectively. Maximum lag order is set to two and optimal lag order (k) is selected based on Schwarz criterion in the ERS test; ***, ** and * indicate rejection of the null hypotheses at the 1%, 5% and 10% significance levels respectively; the critical values are taken from Elliott-Rothenberg-Stock (1996, Table 1), and Kwiatkowski-Phillips-Schmidt-Shin (1992) for the ERS, PP and KPSS tests, respectively.
**Source:** Estimation results

the ERS and PP tests are inconclusive. In the case of the intercept and trend model ERS and KPSS tests prefer income variable to be stationary at level, while PP rejects this conclusion. However, based on the graphical investigation of the variable and general theoretical sense regarding this variable it is concluded that the income variable is stationary in first difference. Therefore, the conclusion is that the used variables are integrated of the first order.

### 4.2 Estimation results

First, based on the Bayesian Information Criterion (BIC), the analysis relies on choosing the number of the polynomials (*p*) and trigonometric pairs (*q*) in the modeling approach. The chosen number of *p* and *q* is 1 and 2, respectively. Next, the analysis applies the Canonical Cointegration Regression (CCR) by Park (1992). Before reporting the results of the TVC approach, the presence of any cointegration relationship should be investigated. The Variable Addition Test (VAT) by Park (1990) is used to test whether there is a long-run relationship between the variables. The results are reported on the right side in Table 4. The null hypothesis of the VAT test states the presence of cointegration among the variables. The VAT test statistic (84.33) is found to be greater than its critical values, thus, rejecting the presence of a long-run relationship; however, this might be due to the small sample size, which is the case here. This is due to the fact that VAT test is asymptotically distributed by a Chi-square test, which requires a large sample size. In order to test the long-run relationship from a robustness perspective, the analysis also used the Pesaran's Bounds test for cointegration (Pesaran and Shin, 1999; Pesaran et al., 2001), as well as the Engle-Granger cointegration test; the results (given in Table 6) document the presence of a cointegration relationship between $CO_2$ emissions and GDP. Based on this result, the analysis proceeds to the next step, through testing the significance of the time-varying coefficient. For these exercises a Wald test suggested by the TVC methodology by Park and Hahn (1999) is employed. The test simply examines the joint significance of the coefficients of polynomials and trigonometric pairs. The null of this test states the insignificance of the time-varying coefficient. As described in Park and Hahn (1999) this test statistics is distributed as Chi-square test with $p + 2q$ degrees of freedom, where *p* is number of polynomials and *q* is number of trigonometric pairs. Since there are five λ's ($p = 1$, $q = 2$), the degree of freedom is 5. The null hypothesis of the test states the joint insignificance across the coefficients. These results are presented on the left side in Table 4. The test statistic (0.24) is very small; thus, accepting the null hypothesis at any significance level. Overall, the findings indicate that the income coefficient is not time-varying or, to put it differently, the change in the income elasticity is not noticeable.

**Table 4** TVC estimations and cointegration test results

| TVC significance test | | | | VAT | | | |
|---|---|---|---|---|---|---|---|
| **Test statistics** | **10% CV** | **5% CV** | **1% CV** | **Test statistics** | **10% CV** | **5% CV** | **1% CV** |
| 0.24 | 9.24 | 11.07 | 15.09 | 84.33 | 7.78 | 9.49 | 13.18 |

**Note:** Null hypothesis for TVC significance test is: $\lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = 0$.
**Source:** Estimation results

Although the time-varying income elasticity is found to be insignificant, the estimation results are reported for further analysis and for future comparison purposes. The detailed results of the long-run estimations with time-varying coefficients are reported in Table 5, while the time-varying income coefficient/elasticity is illustrated in Figure 2.

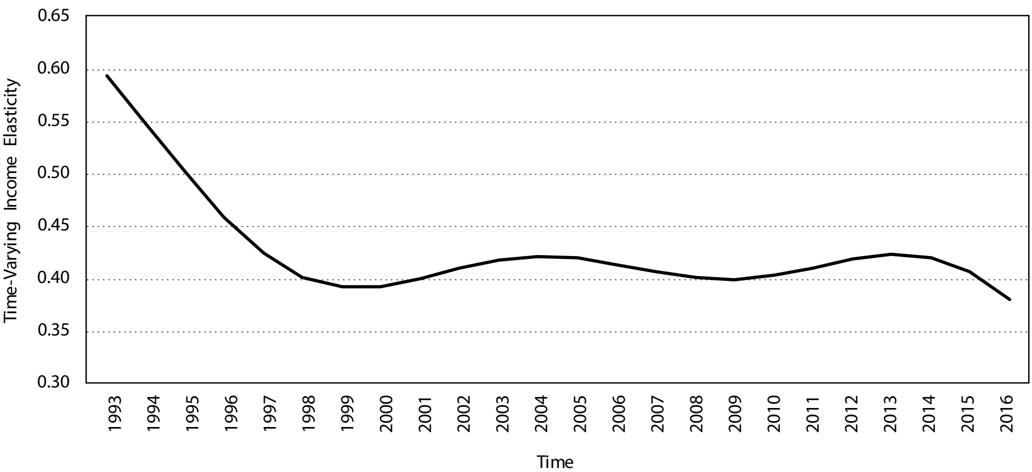
**Table 5** Time-varying coefficient estimates

| Coefficients/ τ(intercept) | | Estimated Parameters | | | | | |
|---|---|---|---|---|---|---|---|
| | | $\lambda_0$ | $\lambda_1$: $\frac{t}{T}$ | $\lambda_2$: $\cos(2\pi \frac{t}{T})$ | $\lambda_3$: $\sin(2\pi \frac{t}{T})$ | $\lambda_4$: $\cos(4\pi \frac{t}{T})$ | $\lambda_5$: $\sin(4\pi \frac{t}{T})$ |
| Estimates | 0.70 | 0.58 | –0.25 | 0.07 | –0.03 | 0.02 | 0.02 |
| P-values | 0.71 | 0.53 | 0.64 | 0.64 | 0.63 | 0.64 | 0.66 |

**Source:** Estimation results

As depicted in Figure 2, the time-varying income elasticity/coefficient reveals negligible change, ranging from 0.38 to 0.59.

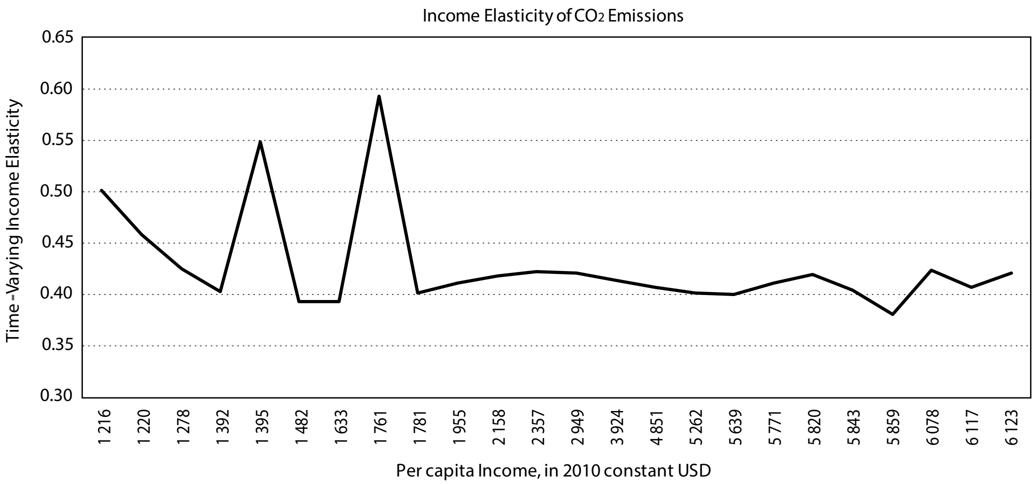
**Figure 2** Time-varying income elasticity, against time




**Source:** Estimation results

The graph of the time-varying income elasticity of $CO_2$ emissions depicted in Figure 2 is not directly comparable with the conventional elasticities, since in the conventional one the graph of the elasticity is depicted against the per capita income level, while in Figure 2 the elasticity sketched against time. To make the finding comparable we matched the varying elasticity values with the appropriate per capita income levels and the values are given as Figure 3. As Figure 3 demonstrates the income elasticity is almost constant with few fluctuations corresponding to the per capita levels 1 216, 1 395 and 1 761 which correspond to three consecutive years, namely 1993, 1994 and 1995 (corresponding to the left side of the TVC in Figure 2), and this relatively high values can be most likely interpreted with inherited emissions level from the Soviet time. As known in the case of linear functional form, which is mainly the case for the developing countries, the income elasticity of emissions is a constant number and the income elasticity of $CO_2$ emissions in Figure 3 resembles this case. The rationale behind the monotonically increasing relationship in case of developing countries can be explained with the fact that, at initial stage of development path economic growth negatively affects environmental quality (see for example, Lieb, 2003; Cole 1999; inter alia) consuming resources and energy, consequently polluting the environment. After some threshold level of income countries can increase environmental quality using some portion of income to address negative results of economic growth. One point to mention is that as demonstrated in Figure 2 the income elasticity is slightly evolving over time, but it is almost constant across the different values of per capita income, as the Figure 3 demonstrates. The finding of constant elasticity for Azerbaijani case can be explained by the lack of necessary socio-economic policies to deal with environmental, safety and lack of social awareness of the importance of environmental quality.

**Figure 3** Varying income elasticity, against income




**Source:** Estimation results

Based on the almost constant income elasticity across income values, which means the elasticity is not a function of drivers evolving over time, it is concluded that the relationship between economic growth and $CO_2$ emissions is a linear relationship. In other words, the income elasticity is constant. Hence, having concluded the constancy of the income elasticity of carbon-dioxide emissions, the investigation is continued with the linear functional specification.

The existence of long-run relationship is tested by employing the Bounds test for cointegration (Pesaran and Shin, 1999; Pesaran et al., 2001) and Dynamic Ordinary Least Squares (DOLS, Saikkonen, 1992; Stock and Watson, 1993) estimation-based Engle-Granger test for cointegration. The results of cointegration tests are given in Table 6. Both tests concluded that the variables share a common trend.

**Table 6** Results of cointegration tests

| **Bounds test** | | **Engle-Granger tests** |
|---|---|---|
| F-statistics | | |
| 11.45 | | Engle-Granger tau-statistics |
| Critical values | | $-4.02^{*}$ |
| 10% | 4.49 | Engle-Granger z-statistics |
| 5% | 5.15 | $-150.62^{***}$ |
| 1% | 6.73 | |

**Notes:** Bounds test = Pesaran's Bounds test for cointegration; Engle-Granger tests based on the DOLS estimations. $^{*,\ ***}$ stand for rejection of no cointegration null hypothesis at 10% and 1% significances levels, respectively.
**Source:** Estimation results

As a next step we used the ARDLBT (Pesaran and Shin, 1999; Pesaran et al., 2001) and DOLS methods to estimate the long-run relationship, and the estimation results are given in Table 7. In the specification, we also added the time trend to consider the impact of technology and innovations on $CO_2$ emissions.

**Table 7** Long-run estimation results

| Variables/methods | ARDLBT | DOLS |
|---|---|---|
| Income, per capita | 0.76*** | 0.63*** |
| P-value | 0.00 | 0.00 |
| Time trend | –0.07*** | –0.06*** |
| P-value | 0.00 | 0.00 |

**Note:** *** stand for rejection of null hypothesis at 1% significance level.
**Source:** Estimation results

As given in Table 7, both methods give quite close results, and the coefficients are statistically significant, having the signs in line with the theoretical expectations.

## 5 DISCUSSION

Based on the above findings, the relationship between environmental degradation and economic growth needs to be investigated starting with a proper functional form, i.e., the income elasticity of $CO_2$ emissions might be time-varying which is caused by different drivers changing over time. The response of the environmental indicator to economic growth in the case of developing country might differ depending on the developmental stage of the country. In other words, the magnitude and the direction of the response might be changing over time, while it is assumed to be constant in the conventional linear functional form approach. The conclusion of the linear relationship (or any other) should be decided based on the detailed investigation of the relationship.

Employing a battery of time series unit root tests, the study concluded that per capita emissions and per capita GDP are integrated of order one. The variables are stationary at first differenced form, hence then the presence of a long-run relationship between them is checked for. Although, the VAT cointegration test rejects the presence of such a long-run relationship, most likely due to the small sample size, the Bounds and Engle-Granger cointegration tests confirm the validity of a cointegration relationship between the variables. The time-varying coefficient was tested for significance using the Wald test, with the results confirming its insignificance. Hence, the response of $CO_2$ emissions to income levels is not time-varying i.e. it is almost constant. Although, the time-varying income elasticity is found to be insignificant, this finding can be interpreted as the change being very small. Moreover, the coefficient itself suggests an interpretable story about the development path of the economy. The Azerbaijani economy witnessed recession during the period 1991–1995, a stable economic growth path in the period 1996–2003, rapid economic growth during 2004–2010, and a recovery period after 2010 (Mikayilov et al., 2017c). As it can be seen from Figure 2, the time-varying income elasticity of $CO_2$ emissions almost 'replicates' the developmental path of the economy. The decrease in emission levels during the recession period can be explained by the collapse of the industrial sector, following the collapse of the Soviet regime; that is, it is not a gain coming from environmental concerns, rather it is the result of the downfall of the whole economy. The slight increase of emission levels after 1998 is the result of the reinvigoration of the economy, focusing first on the necessary needs and unconsciously 'ignoring' the need for environmental quality, which is a case across all countries in a similar growth stage. The fact that the time-varying income elasticity of $CO_2$ emissions is fluctuating over time is not the result only of this study; Liddle and Messinis (2016) for Belgium, Spain, New Zealand, Norway, Switzerland and US, and Mikayilov et al., (2018 b) for Finland, Germany and Sweden provided similar results. The current study documented that the time-varying income elasticity of $CO_2$ emissions was positive. Liddle and Messinis (2016) also found a positive income elasticity of $CO_2$ emissions for the cases of Australia, Canada, Spain, Ireland, Italy, the Netherlands, New Zealand, Norway, and US. Moreover, Mikayilov et al. (2018b) found a positive income elasticity of emissions in twelve advanced economies.

With respect to the magnitude of income elasticity, it also worth noting that our findings are very close to those of other studies. More specifically, our results, ranging from 0.38 to 0.59, with the time-varying coefficient, and 0.63 to 0.76 in the case of the constant elasticity model are very close to those provided by Brizga et al. (2013) and by Mikayilov et al. (2018a). Brizga et al. (2013) found that the income elasticity of $CO_2$ emissions was 0.86, while using different methods, Mikayilov et al. (2018a) estimated it ranging from 0.70 to 0.82.

The sign of time trend, being negative, also confirms the belief in technological changes mitigating the environmental degradation.

Considering the time-varying behavior of income elasticity, one can conclude that the need for environmental quality turns out to be the priority issue when other necessary needs are satisfied, while it becomes secondary when basic necessities are unfulfilled. This conclusion is in line with the behavior of the economy and the society as a whole. Given that income elasticity is always positive, it can be concluded that the EKC hypothesis does not hold in the case of Azerbaijan, which is in line with the findings of the studies like Brizga et al. (2013), Narayan et al. (2016), Mikayilov et al. (2017a, 2017b, 2018a), Ito (2017), and Mitic et al. (2017). Although this study managed to test different functional specifications, it considers the shortcomings of the earlier papers, such as: the constant responses of emissions to income over time, the limitations of the functional forms to the cubic or smaller cases, and the omitted variable issue.

## CONCLUSION AND POLICY IMPLICATIONS

The relationship between $CO_2$ emissions, and the magnitude and behavior of the response of $CO_2$ emissions level to increases in income, is one of the main concerns of our world. All countries strive to mitigate the negative impact of the uncontrolled and unsustainable economic growth on the environmental degradation/pollution issue. In this regard, both the Kyoto protocol and the Paris Agreement, as well as similar institutional pacts, put certain requirements in front of both developed and emerging countries. The conventional approaches modeling the relationship between $CO_2$ emissions and economic growth are faced with substantial debates, as new approaches are needed to confront their shortcomings. In this regard, the time-varying coefficient cointegration approach could be one of the alternative methods, which considers the likelihood the income elasticity that changes over time, since the response of $CO_2$ emissions to changes in income levels might not be constant over time. In addition, this method also addresses the contradicting findings resulting from the application of different polynomials of different orders. This method does not use the different powers of a variable (say income proxy) integrated in the first order, which is debatable from a theoretical point of view (Müller-Fürstenberger and Wagner, 2007).

The emissions-economic growth relationship gains special importance in the case of developing countries with higher growth targets and expectations, since these countries show an important (and increasing) share of global pollution levels. In this regard, the current study which contributed to the relevant literature is twofold. Firstly, by combining the use of a new approach in the case of a developing economy, i.e. Azerbaijan. Secondly, the study employed the time-varying coefficient cointegration approach using data spanning the period 1992–2016.

The results showed that the use of the time-varying coefficient cointegration approach was more relevant to investigate the environmental degradation-economic growth relationship, since it captures the different responses of ecological indicators to the different stages of economic growth. The use of this methodology and its associated results indicates that income elasticity of $CO_2$ emissions was slightly varying over time, while the trajectory of the relationship mainly kept the same direction.

These findings indicated that the EKC hypothesis did not hold in the case of Azerbaijan. In recessionary periods, environmental quality is deemed unimportant requirement for society. However, it becomes the concern when the main necessities are satisfied.

The results of the study also pinpointed one of the main targets of sustainable development goals, i.e. using current resources while considering the needs of the future. The economy might have to cope with the lack of necessary goods and services, based on the increase of the emissions response to economic growth, close to the end of the varying elasticity (Figure 2). Although, the country gained a significant improvement in emissions' mitigation, the results highlighted that as a developing country, Azerbaijan still should take significant measures in relevance to the reduction of emission levels, such as the employment of energy efficient technologies, increasing the infrastructure associated with the transmissions and distribution quality, which in turn minimize the losses of energy use. Taxes on carbon-emissions intensive activities and programs targeted to increase social awareness regarding negative and unsolvable problems caused by unnecessary use of natural resources might also help to mitigate the increase of those emission levels. The results of the study enable to conclude that in order to make proper decisions, policymakers should explicitly take into account the varying feature of the response of the environmental indicators to changes in the growth at different stages of the economy. In other words, as the time-varying trajectory of the income elasticity in Figure 2 demonstrates, if the developing economy is facing recession or stagnation periods the fall in the level of $CO_2$ emissions (or other environmental indicator) is not necessarily reflected by the current economic policies followed by that country. Instead, it might be caused by considerable decrease in overall production level, or by the decrease of the size of the emission intensive imported goods, and in order to keep the sustainable development path, environmentally friendly policies should be continued. On the other hand, the increasing path of the income elasticity might not imply the environmental degradation if the country is following the sustainable development strategy, but the policies causing the dramatic changes in income level should be considered with caution.

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# ANNEX – Abbreviations used in the text

EKC = Environmental Kuznets Curve; NAFTA = North American Free Trade Agreement; $CO_2$ emissions = Carbon-dioxide emissions; CIS = Commonwealth of Independent States; QFF = Quadratic functional form; QLF = Quadratic functional form in logarithms; IUS = Inverted U-shaped; FMOLS = Fully Modified Ordinary Least Squares; US = U-shaped; GMM = Generalized Method of Moments; LLF = Log-linear function; CLF = Cubic Functional form in Logarithms; ARDLBT = Autoregressive Distributed Lags Bounds Testing; DOLS = Dynamic Ordinary Least Squares; OLS = Ordinary Least Squares; PMGE = Pooled Mean Group Estimator; VECM = Vector Error Correction Method; NLS = Non-linear Least Squares Method; EIR = Emission-Income Relationship; MI = Monotonically Increasing; MD = Monotonically Decreasing; LS = L-shaped; NS = N-shaped; USSR = Union of Soviet Socialist Republics; STIRPAT = Stochastic Impacts by Regression on Population, Affluence and Technology; GDP = Gross Domestic Product; TVC = Time-Varying Coefficient Cointegration; ERS = Elliott-Rothenberg-Stock test; PP = Phillips and Perron test; KPSS = Kwiatkowski-Phillips-Schmidt-Shin test; StDev = Standard Deviation; CoV = Coefficient of Variation; VAT = Variable Addition Test; CV = Critical Value.