AN ECONOMETRIC ANALYSIS OF AIR CONTAMINATION IN UZBEKISTAN

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Abstract. *Pollution and the economy have been closely interconnected throughout the entirety of human history. The understanding of the relationship between environmental degradation and economic development is incomplete as a result of disciplinary prejudices. The aim of this research is to comprehend the dynamic correlation between air pollution and the economy of Uzbekistan. Additionally, it seeks to examine the presence of the Environmental Kuznets Curve (EKC) to identify the most effective policy options for reducing emissions while sustaining economic growth. This study utilized the Bayer-Hanck Cointegration test and Granger Causality tests to accomplish its objectives. The presence of Bayer-Hanck cointegration suggests a durable connection between air pollution and economic growth. Furthermore, the Granger causality test demonstrates that there is a causal relationship between economic growth and the three air pollutants, with a significance level of 0.05. This study seeks to address a gap in the current literature by examining the relationship between air pollutants and economic growth. It attempts to investigate the EKC hypothesis and the effects of air pollution on economic growth specifically in Uzbekistan.*

Keywords: Bayer-Hanck, Carbon emissions, Economic growth, EKC.

O'ZBEKISTONDA HAVO IFLOSLANISHINIG EKONOMETRIK TAHLILI

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Toshkent davlat iqtisodiyot universiteti

Annotatsiya. Atrof muhitning ifloslanishi va iqtisodiyot butun insoniyat tarixi davomida bir-biri bilan chambarchas bog'langan. Ushbu tadqiqotning maqsadi havoning ifloslanishi va O'zbekiston iqtisodiyoti o'rtasidagi dinamik bog'liqlikni aniqlashdir. Bundan tashqari, u iqtisodiy o'sishni ta'minlashda emissiyalarni kamaytirish uchun eng samarali siyosat variantlarini aniqlash uchun Atrof-muhit Kuznets egri chizig'ining (EKC) mavjudligini o'rganishga intiladi. Ushbu tadqiqot o'z maqsadlariga erishish uchun Bayer-Hanck Cointegration testi va Granger Causality testlaridan foydalanadi. Bayer-Hanck kointegratsiyasining mavjudligi havoning ifloslanishi va iqtisodiy o'sish o'rtasidagi mustahkam bog'liqlikni ko'rsatadi. Bundan tashqari, Granjer sabab-oqibatlilik testi iqtisodiy o'sish va havoni ifloslantiruvchi uchta omil o'rtasida sababiy bog'liqlik mavjudligini ko'rsatadi, muhimlik darajasi 0,05. Ushbu tadqiqot havoni ifloslantiruvchi moddalar va iqtisodiy o'sish o'rtasidagi munosabatlarni o'rganish orqali joriy adabiyotdagi bo'shliqni bartaraf etishga intiladi. U EKC gipotezasini va havo ifloslanishining O'zbekistonning iqtisodiy o'sishiga ta'sirini o'rganishga harakat qiladi.

Kalit so'zlar: Bayer-Hanck, Karbonad angidrid emissiyasi, Iqtisodiy o'sish, EKC.

ЭКОНОМЕТРИЧЕСКИЙ АНАЛИЗ ЗАГРЯЗНЕНИЯ ВОЗДУХА В УЗБЕКИСТАНЕ

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Аннотация. Загрязнение окружающей среды и экономика были тесно взаимосвязаны на протяжении всей истории человечества. Понимание взаимосвязи между деградацией окружающей среды и экономическим развитием является неполным из-за дисциплинарных предрассудков. Целью данного исследования является понимание динамической взаимосвязи между загрязнением воздуха и экономикой Узбекистана. Кроме того, он стремится изучить наличие экологической кривой Кузнеца (ЭКК) для определения наиболее эффективных вариантов политики по сокращению выбросов при сохранении экономического роста. В этом исследовании для достижения своих целей использовались тест коинтеграции Байера-Ханка и тесты причинности Грейнджера. Наличие коинтеграции Байера-Ханка предполагает прочную связь между загрязнением воздуха и экономическим ростом. Кроме того, тест причинности Грейнджера показывает, что существует причинная связь между экономическим ростом и тремя загрязнителями воздуха с уровнем значимости 0,05. Это исследование направлено на устранение пробела в современной литературе путем изучения взаимосвязи между загрязнителями воздуха и экономическим ростом. В нем предпринята попытка исследовать гипотезу ЕКС и влияние загрязнения воздуха на экономический рост, особенно в Узбекистане.

Ключевые слова: Bayer-Hanck, выбросы углерода, экономический рост, ЕКС.

Introduction.

Air pollution encompasses a diverse array of contaminants that are generated by one or more sources. According to a survey conducted by the European Commission, almost 82% of Europeans are subjected to air pollution (Gehrsitz, 2017). Poor air quality is a significant environmental issue that affects individuals owing to the presence of air pollutants such ozone, nitrogen dioxide, and carbon dioxide (Collivignarelli et al., 2020). Urban regions experience higher levels of air pollution as a result of elevated traffic and population density (Amin et al., 2020).
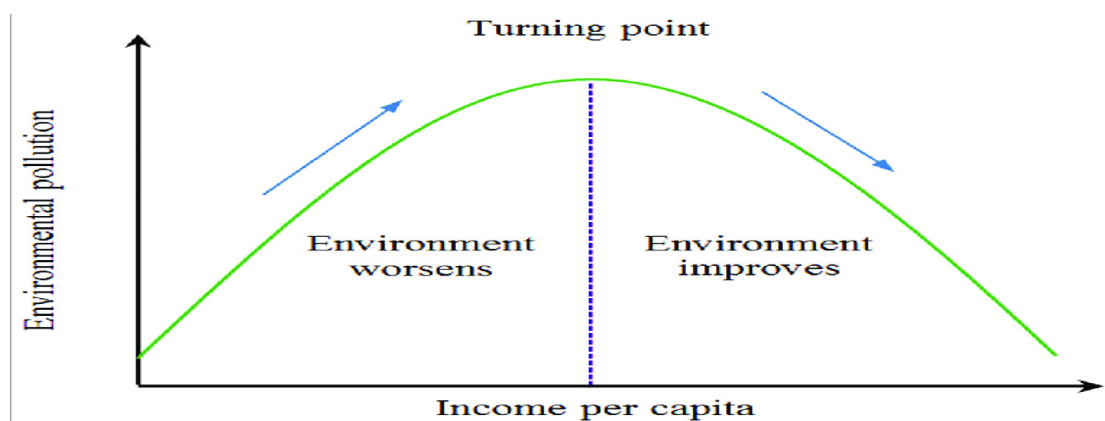
The correlation between pollution and economic growth has garnered significant scrutiny in the realms of both scientific research and social sciences (Qiu et al., 2019). The Environmental Kuznets curve (Ozokcu and Ozdemir, 2017) has made it difficult to see some of the less apparent links between economic growth and environmental impacts. The ecological system's carrying capacity is a crucial issue that must be considered. Furthermore, a significant portion of research is conducted inside limited contexts, which prevents us from evaluating an integrated framework. In less developed nations, where pollution levels are rapidly increasing, there are sometimes contradictory accounts regarding economic advancement and human development. Air pollution can have negative effects on trees and agricultural yields in multiple ways (Rupakheti, 2015). Ground-level ozone is likely to cause a decline in agricultural and forest yields, hinder tree growth, and make plants more susceptible to diseases, pests, and other challenges (Jebli et al., 2016).

Due to the limited availability of empirical data in Uzbekistan, the objective of this study is to assess the relationship between air pollution and economic growth in Uzbekistan, both in the short and long term, using the Environmental Kuznets Curve (EKC) hypothesis. This work is expected to make a significant contribution towards the development of environmentally-friendly economic policies for future environmental policy design. If stricter regulations are not implemented, the levels of air pollution emissions and concentrations are projected to increase fast, which will pose a significant risk to both human health and the environment. Air pollution

is anticipated to have detrimental health consequences, leading to substantial economic expenses. These expenses are likely to manifest as considerable yearly global welfare costs at both the regional and sectoral levels (Jalil and Feridun, 2011).

Literature review.

Kuznets (1955) proposed the theory that there is a curvilinear relationship between income inequality and economic development, characterized by an inverted U shape. The concept was rearticulated in the 1990s as the Environmental Kuznets Curve, which establishes a correlation between economic growth/income and environmental conditions (EKC). During the initial phases of growth, there is a positive correlation between GDP per capita and CO_2 emissions per capita. Following the tipping point, there is a gradual reduction in CO_2 emissions per person as a certain income threshold is reached. This is because countries and individuals become more sensitive to environmental concerns, leading to a decrease in environmental degradation through the implementation of preventive measures. Figure 1 illustrates a clear relationship between income and environmental deterioration, which follows an inverted U-shaped pattern. In their 1991 publication, Grossman and Krueger presented an essay that aimed to prove a correlation between air quality and economic growth, thus popularizing the Environmental Kuznets Curve (EKC) theory. Early empirical research of the Environmental Kuznets Curve (EKC) have focused on two variables: CO_2 emissions and GDP per capita. These two variables, CO_2 emissions and GDP per capita, have been used in these investigations.

Figure 1. Environmental Kuznets curve

Several previous research have investigated the correlation between CO2 emissions and economic growth in relation to environmental degradation. The study examined the long-term relationship between air pollution and economic growth by analyzing the idea known as the environmental Kuznets Curve (EKC). The EKC theory was founded on the concept of an Inverted-U relationship between the level of carbon emissions and the level of income within a specific country. Grossman and Krueger (1995) were the pioneering researchers who examined the correlation between per capita income and environmental conditions. They were the first to propose the Environmental Kuznets Curve (EKC) hypothesis as a means to explore this relationship. Nevertheless, their empirical analysis encountered issues in relation to the EKC hypothesis as it yielded divergent outcomes. The EKC theory has received support from several investigations, each yielding distinct conclusions. Several scholars have presented reasons in favor of the Environmental Kuznets Curve (EKC) hypothesis, as shown by Rauf et al. (2018), Pata (2018), Cosmas et al. (2019), Rana and Sharma (2019), Bekun et al. (2020), and Wasti and Zaidi (2020). However, several research challenge the Environmental Kuznets Curve (EKC) theory, as evidenced by the works of Sarkodie (2018), Koc and Bulus (2020), Dogan and Inglesi-Lotz (2020), and Leal and Marques (2020).

Gökmenoğlu and Taspinar (2016) conducted a study in Turkey to examine the correlation among foreign direct investment (FDI), economic growth, energy consumption, and CO_2 emissions from 1974 to 2010. The researchers employed the Toda Yamamoto causality technique and their results revealed a reciprocal causation between CO_2 emissions and FDI inflows, as well as between CO_2 emissions and energy. Moreover, a unidirectional relationship was found between FDI inflows and real growth, as well as between energy use and real growth.

In their study, Saboori and Sulaiman (2013) conducted an analysis of the cointegration and causative link between energy consumption, CO_2 emissions, and economic growth for each individual ASEAN member country. The researchers found that the economies of all five nations showed cointegration between economic growth, CO_2 emissions, and energy consumption. They also observed a positive correlation between CO_2 emissions and energy consumption in both the short and long run. The correlation between CO_2 emissions decrease and economic growth was observed exclusively in Singapore and Thailand, while the opposite trend was observed in Indonesia and the Philippines.

Hanif (2018) employed a generalized linear model (GMM) to assess the correlations among economic growth, fossil fuel consumption, renewable energy usage, CO_2 emissions, urban expansion, and solid fuel consumption in the economies of Sub-Saharan Africa. The study encompassed the years 1995 to 2015. The study revealed that the utilization of fossil and solid fuels had a beneficial effect on CO_2 emissions, whereas the utilization of renewable energy had an adverse impact on CO_2 emissions.

Heidari et al. (2015) investigated the relationship between EC (environmental degradation), CO_2 emissions, and GDP (economic output) in the ASEAN-5 countries. They employed the Panel Smooth Transition Regression approach, which considers variations and changes over time. Nonlinearity was detected by employing two threshold settings. Environmental degradation increased in parallel with economic growth in regime one, but this correlation did not exist in regime two. Granger causality analysis revealed that energy use is responsible for CO_2 emissions in both systems.

Zhou and Liu (2016) examined the impact of income, demographic variables, and carbon dioxide emissions. The study employed the STIRPAT approach paradigm, covering the time frame from 1990 to 2012. Income has emerged as the primary catalyst for the escalation of CO_2 emissions in China. The study's findings indicate that demographic characteristics do not have any impact on the increase of CO_2 emissions. Except for western China, urbanization has led to a rise in energy consumption and CO_2 emissions. To address the environmental impact in China, it is very advisable for the government to implement measures that control the pace of urbanization and encourage energy efficiency.

Khoshnevis and Beygi (2018) employed PMG and Granger Causality methodologies to investigate the correlation between CO_2 emissions, trade openness, financial development, renewable energy, and economic growth in a sample of 25 African countries. The findings indicated a one-way relationship where renewable energy had a causal effect on CO_2 emissions, and real production also had a causal effect on CO_2 emissions. In addition, Munir et al. (2020) investigated the correlation between CO_2 emissions and economic and energy factors from 1980 to 2016. The researcher discovered a loop causation in Malaysia, Singapore, Thailand, and the Philippines, which connects economic expansion to the emissions of carbon dioxide (CO_2). During the study conducted in Indonesia, Malaysia, and Thailand, it was observed that there is a unidirectional relationship between economic growth and energy consumption. Similarly, in Singapore, there are evidence of a one-way causal relationship from economic growth to energy usage. After doing a literature study, a research gap on research efforts on air pollution in Uzbekistan was observed. Therefore, this research was conducted to address this gap.

Methodology.

The data utilized for this research is derived from secondary sources, specifically World Bank publications, spanning the years 2000 to 2020. The model is trained to forecast Uzbekistan's economic growth (GDP Per Capita) using air pollution variables including nitrogen dioxide, ozone, and carbon dioxide. The functional regression model is represented by the following equation:

$$\text{GDP per Capita} = \beta_0 + \beta_1 CO_2 + \beta_2 NO_2 + \beta_3 O_3 + \cdots \beta_n Xn + \varepsilon_t \qquad (1)$$

Where β_1 to β_3 are the coefficient estimates of the air pollution variables. Table 1 shows the variables used in this analysis.

Table 1.

Variables description and data source

Variable	Definition	Abb.	Period	Source
Economic growth	GDP "per capita"	GDP	2000 − 2020	WDI
Carbon dioxide	CO_2 "emitted from fossil consumption in kilotons"	CO_2	2000 − 2020	WDI
Nitrogen Dioxide	NO_2 "emitted from fossil consumption in kilotons"	NO_3	2000 − 2020	WDI
Ozone pollution	O_3 "emitted from fossil consumption in kilotons"	O_3	2000 − 2020	WDI

WDI: World Bank Development Indicators

In order to handle ARMA (g,r) models with unknown orders, Augmented Dickey-Fuller (1984) improved upon the basic autoregressive unit root test. The ADF test is the name given to this particular test. The test is sometimes referred to as the augmented Dickey-Fuller (ADF) test. The model states that the lag time in auto-regression grows according to the sample size, T, at a controlled pace of $T^{(1/3)}$. The fundamental equation of the model is as follows:

$$N_t = \beta_0 D_t + \propto N_{t-1} + \pi_t \qquad (2)$$
$$\propto (V)U_t = \theta(V)\varepsilon t, \varepsilon t \sim MZ(0,\sigma 2) \qquad (3)$$

The null hypothesis of the Augmented Dickey-Fuller (ADF) test states that a time series y_t is integrated of order 1 (I(1)) if the alternative hypothesis is that it is integrated of order 0 (I(0)). The null hypothesis of the Augmented Dickey-Fuller (ADF) t-test is:

$$H_0: \beta = 0$$
$$H_1: \beta < 0$$

This is predicated on the idea that the intricacies of the data exhibit an ARMA configuration. The ADF test is conducted to ascertain the presence of a regression in the test.

$$N_t = \gamma' S_t + \propto N_{t-1} + \sum_{j=1}^{p} \delta_j \Delta N_{t-j} + \rho_t u_t \qquad (4)$$

The deterministic component is represented by the symbol D_t, while the expression Δy_{t-j} indicate the presence of serial correlation.

The t-statistic for the Augmented Dickey-Fuller (ADF) test and the normalized bias statistic are as follows:

$$ADF_t = l_{\propto=1} = \frac{\hat{\propto}-1}{SE(\propto)} \qquad (5)$$

ADF$_t$ demonstrates asymptotic $t_\phi = 1$ distributions when white noise errors are present, provided that p is appropriately chosen.

Time series in econometric analysis are considered integrated when several series are cointegrated individually, however there exists a linear combination of these series that has a lower level of cointegration. Furthermore, it has been shown that these cointegration procedures have different theoretical foundations and yield contradictory results. It has also been observed that the effectiveness of cointegration approaches is influenced by the choice of error estimators (Pesavento, 2004). In order to strengthen the effectiveness of the cointegration test, the Bayer-Hanck test, developed by Bayer and Hanck in 2013, combines various tests such as Engle and Granger, Phillips and Outliers, Johansen, Boswijk, and Banerjee. This joint test-measurement is particularly useful for detecting the absence of cointegration.

Given its ability to combine many individual cointegration test results to yield a more definitive finding, this innovative approach is also employed in this analysis to ascertain the presence of a cointegrating relationship between Economic growth and its determinant in Uzbekistan. Bayer and Hanck (2013) proposed a method to integrate the calculated significance level (p-values) of each cointegration test using Fisher's formulas:

$$E - J = -2[LN(PH_E) + LN(PH_J)] \qquad (6)$$
$$E - J - B - BM == -2[LN(PH_E) + LN(PH_J) + LN(PH_B) + LN(PH_{BM}) \qquad (7)$$

The p-values of various independent cointegration tests, including those performed by Engle and Granger (1987), Johansen (1988), Boswijik (1994), and Banerjee et al. (1998), are denoted as PHE, PHJ, PHB, and PHBM, respectively. If the calculated Fisher statistics exceed the critical values provided by Bayer and Hanck (2013), it is possible to reject the null hypothesis that there is no cointegration.

Results.

Given that time series data were utilized in this investigation, it was crucial to assess if the data exhibited stationarity at their original levels or if they needed to be transformed by differencing to achieve stationarity. The validity of the results produced from the data analysis was ensured. This study used the initial generation unit root tests, which disregard structural breakdowns but were frequently used in the economic growth literature. Specifically, it utilizes the Augmented Dicky-Fuller, 1987 (ADF) test. All unit root tests, without any exceptions, assume non-stationarity as the null hypothesis. The data series was tested for stationarity using the Augmented Dickey-Fuller (ADF) methods.

Table 2.

Augmented Dickey fuller unit root tests

Variables	Level t stats	p-value	1st Diff. t stats	p-value
CO_2	-2.874	0.1923	-4.5482^*	0.000
NO_2	-0.894	0.0013	-8.2419^*	0.000
O_3	-0.192	0.0000	-7.0845^*	0.000
GDP	-2.998	0.0341	-4.6494^*	0.000

Table 2 displays the outcomes of the unit root analysis conducted on the factor components for Carbon Dioxide, Nitrogen Dioxide, Ozone Pollution, and GDP Per capita.

All of the series exhibit a unit root, indicating that they are non-stationary at their levels. However, the series are stationary when considering their beginning differences, as demonstrated in Table 2. The results of the ADF unit root test suggest that CO2, NO2, O3, and GDP are all integrated at the same order, specifically I(1). The cointegration relationship among series can be analyzed using the Bayer-Hanck (2013) cointegration approach, which accounts for different structural breaks.

Table 3.

Bayer and Hanck combine cointegration analysis

Estimated models	EG-JH-BA-BO	Cointegration
$GDP = f(CO_2, NO_2, O_3)$	41.124 $*$	Yes
Significance level	Critical value	
1% level	33.197	
5% level	22.738	
10% level	16.868	

The results from the long-run nexus between the variables utilizing the Bayer and Hanck test are reported in Table 3 below. Given that the unit root test indicates that all variables have an integration order of I(1), we employed the combined cointegration test. The outcome displays the Fisher-statistics for the combined tests of EG-JH-BO-BA, namely the tests developed by Johansen (1995), Boswijk (1995), and Bannerjee et al. (1998). The Fisher-statistics value for GDP exceeds 10% of the critical values. The levels of CO_2 and NO_2 surpassed the threshold values of 5%. The Fisher-statistics value for O3 exceeds 10% of the critical values. These statistical tests enable us to reject the null hypothesis that there is no long-term link and confirm the presence of cointegration between GDP and the explanatory factors.

Table 4.

Granger causality wald test

Equation	Prob > Chi-2
GDP cause ALL	$p < 0.05$
NO_2 cause ALL	$p < 0.05$
CO_2 cause ALL	$p < 0.05$
CO_2 cause ALL	$p < 0.05$

The following presents the results of a Granger causality test, indicating that GDP has a substantial causal effect on CO_2, NO_2, and O_3 at a 5% significance level. This indicates that there is a causal relationship between GDP and the three air contaminants examined in this study. In addition, both CO_2 and NO_2 have a substantial impact at a 0.05 level of significance, as indicated in Table 4.

Conclusion.

This study aims to investigate the relationship between air pollution in Uzbekistan from 2000 to 2020 using the Environmental Kuznets Curve. This study used three distinct pollution metrics to evaluate the air quality. The three gases are carbon dioxide (CO_2), nitrogen dioxide (NO_2), and ozone (O_3).

In Uzbekistan, there are standard factors used to regulate air quality. Initially, the stationarity of variables was assessed using the Dickey-Fuller unit root test. Subsequently, the data was analyzed using the cointegration and Granger causality method proposed by Bayer-Hanck (2013). The results of the Bayer-Hanck cointegration method indicate the presence of a stable and long-term equilibrium relationship between the variables. The Granger causality analysis demonstrates that there is a causal relationship between GDP per capita and air pollution. However, these actions alone are inadequate to mitigate environmental pollution without compromising Uzbekistan's economic growth.

Consequently, the following supplementary measures for attaining these objectives may be proposed. These measures encompass the modification of regulations pertaining to the reduction of greenhouse gas emissions from industry, transportation, and heating. Additionally, they involve the promotion of bio-diesel fuel as a substitute for fossil fuels, the enhancement of alternative energy sources, specifically solar and wind energy projects, the elevation of public consciousness, and the provision of tax incentives to support environmentally friendly investments.

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