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The Impact of Income Inequality and Income Level on CO_2 Emissions in Central Asian Countries

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ABSTRACT

Income inequality has recently viewed not only as a factor affecting social stability, but also as a predictor of environmental sustainability and public health. This study examines the impact of income inequality and income levels on CO_2 emissions in Central Asian countries. The aim of the article is to empirically test the environmental Kuznets curve (EKC) hypothesis and to analyze the relationship between income inequality and CO_2 emission level. The analysis is based on panel data for Central Asia using regression and polynomial models. An additional analysis of socio-economic and environmental indicators provided deeper insight into the structural problems faced by the region. The study results confirmed the existence of an inverted U-shaped EKC, describing the relationship between income level and CO_2 emissions. Regarding the impact of income inequality on environmental pollution, a country case study of Kazakhstan revealed no direct effect of income inequality on emissions. The impact of income inequality on CO_2 emissions is indirect, occurring through other factors such as the industrial structure of the economy and urbanization. Therefore, in developing policies aimed at reducing emissions, it is necessary to apply an integrated approach, that takes into account the interconnection of social, economic, and environmental factors.

Keywords: Income Inequality, CO_2 Emissions, Central Asia, Sustainable Development, Environmental Kuznets Curve
JEL Classifications: D63, O53, Q51, Q56

1. INTRODUCTION

In recent years, the problem of income inequality has been particularly significant, acting as a barrier to the sustainable development of countries. Modern scientific research shows that rising income inequality can lead to an increase in environmental pollution, including carbon dioxide CO_2 emissions, and consequently, to deteriorating public health.

These problems are especially pronounced in Central Asian countries, where both socio-economic disparities and high vulnerability to climate change are evident. The region is characterized by a relatively high dependence on fossil energy sources, inefficient use of natural resources, a raw-material orientation of export structure, growing urbanization, and changes in consumption patterns. All of this inevitably leads not only to the concentration of income among a limited part of the population and increased inequality, but also to the emergence of environmental problems related to environmental pollution and climate change.

The relationship between inequality, economic development and environmental risks is reflected in the Regional Climate Change Adaptation Strategy for Central Asia, adopted in 2023. According to this document, by 2030, the Central Asian countries will increase the resilience of the region's economies to the effects of climate change within the framework of the Paris Agreement by strengthening interstate coordination. In this context, the analysis of the impact of income inequality on greenhouse gas emissions is of particular interest. However, despite the urgency of the issue, there is a lack of research on the relationship between income inequality and environmental burden in the Central Asian region, creating a gap in the understanding of how socio-economic factors affect environmental sustainability.

This study assessed the relationship between income levels and CO_2 emissions in Central Asian countries (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan) by empirically testing the EKC hypothesis, as well as analyzing the impact of income inequality on emissions using multiple linear regression. The indirect impact of income inequality on environmental pollution through the economic structure and the level of urbanization in the countries has been revealed. The limitation of the study was the lack of a continuous time series of data (2000-2023) for the Gini coefficient on the website of the statistical agencies of Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan, which made it impossible to assess the impact of income inequality on emissions in the Central Asian region as a whole. This limitation allowed us to conduct only a country case study of Kazakhstan. The analysis provides important conclusions for sustainable development policy, where one of the main elements is the issue of reducing greenhouse gas emissions and overcoming inequality.

The article has the following structure. The Literature Review section includes a brief overview of studies on the impact of inequality and income levels on environmental pollution. The Methods section provides information about the selected research methods and the data used in the study. The Data and Findings section examines the results of the EKC hypothesis testing and the analysis of the impact of income inequality on CO_2 emissions. The final section outlines the main conclusions of the conducted research for Central Asian countries and, in particular, on Kazakhstan, and identifies directions for future research.

2. LITERATURE REVIEW

Most of the previous research on income inequality focuses on its economic and social aspects. These works examine the impact of income disparities in the country's population on economic growth, investment, access to education and medical services, social stability, and other factors. However, in recent years, researchers have increasingly turned their attention to another important aspect of income inequality – the environmental aspect. There is a growing number of studies showing that rising income inequality leads to environmental degradation, specifically through increased resource consumption, carbon dioxide CO_2 emissions, and other forms of pollution. The wealthiest segment of the population, with higher purchasing power, consume more energy and resources, and use more energy-intensive goods and services. Low-income populations are exposed to pollution and have limited access to quality medicine, environmentally friendly technologies, and infrastructure. In addition, income inequality can be a result of economic structure. This is especially evident in countries with a resource-dependent economy, where incomes are concentrated among certain population groups. Such approaches introduce new challenges in the study of income inequality, highlighting its impact not only on the economy and society, but also on environmental sustainability.

There are two main research directions that reflect the purpose of this work. The first focuses on the relationship between income inequality and environmental pollution. Studies show that countries with high level of inequality tend to greater environment degradation and increased consumption of natural resources.

Thus, researchers Apeti et al. (2025), Khan et al. (2025), after conducting a regression analysis, concluded that the wealthiest individuals make a disproportionately large contribution to the increase in CO_2 emissions. The impact of income inequality on CO_2 emissions inequality occurs both through the deterioration of the quality of institutions, where democratic mechanisms and environmental laws often function less effectively, and through increased consumption level among the wealthy and their higher marginal propensity to emissions. As policy measures, they propose the introduction of a progressive income tax or wealth tax regime, social programs for low-income people, and carbon tax policy.

The role of institutional quality in the relationship between income inequality and CO_2 emissions is also considered in the work of Yang et al. (2022). In their study, they identified a positive relationship between income inequality and emissions, but when a factor determining institutional impact is included in the model, the relationship becomes negative. In countries with well-developed institutions, the negative impact of income inequality on emissions is less pronounced, which confirms the influence of the quality of public administration in shaping sustainable development policies.

A positive relationship between CO_2 emissions and the Gini coefficient has been found in high-income countries (Wang and Yuan, 2022; Cheng et al., 2023; Dorn et al., 2024). At the same time, Coşkun (2025) highlights on the distinction between consumption-based and production-based emissions, which shows the impact of the structure of national economies on income inequality and the environment. The research results are aimed at developing measures to reduce the income gap in order to achieve the Sustainable Development Goals (SDGs) by forming balanced policies.

In addition, researchers do not ignore other factors that characterize the economic growth of countries (urbanization of the population, the development of trade and services, energy consumption, etc.), which also negatively affect the environment. For example, the work of Yazdi and Dariani (2019) revealed a bidirectional causal relationship between income levels, urbanization, and CO_2 emissions. Such results make it possible to build a policy on migration and urban infrastructure development.

The second area focuses on the analysis of the EKC, according to which environmental pollution in a country increases with rising income levels, but after reaching a certain threshold of economic development, it begins to decrease. At the same time, researchers analyze various factors through which income inequality can influence pollution levels.

Examples of such studies include the works confirming the EKC hypothesis (Destek et al., 2018; Khan et al., 2022; Li et al., 2024; Caporin et al., 2024; Wu et al., 2025). Their analysis also revealed the impact of the number of poor people, the level of urbanization, geopolitical risks and increased energy intensity on emissions, which leads to the need to adapt the developed policies to specific conditions in the regions. When studying the existence of the EKC hypothesis Ojaghlou and Ugurlu (2023), Ridwan et al. (2024) took into account such factors as the level of urbanization, industrialization and the development of the service sector. They showed that the growth of urbanization and the expansion of service sector increase CO_2 emissions, while the process of industrialization has a relatively minor impact. These studies also highlight the need to develop adaptive industrialization and urbanization strategies to reduce CO_2 emissions.

Chu (2020), Khezri et al. (2022), Ulucak et al. (2023), Ghazal et al. (2024) by adding the economic complexity index into their models show that new directions in the structure of the economy can positively affect environmental degradation. This is due to the shift of the economy towards high-tech and environmentally friendly technologies and industries.

For the Central Asian countries, this issue remains largely unexplored. Existing research is mainly focused on studying overall emission level and achievement of the SDGs, but does not address the relationship between income inequality and the environment. In this regard, it is relevant and practically significant to apply existing models (in particular, the EKC) to Central Asian countries.

3. METHODS

To identify the relationship between income and emissions, the EKC was used, suggesting an inverse U-shaped relationship between income and pollution levels. That is, economic growth, involving the development of infrastructure and service sector, as well as increased urbanization, leads to significant increase in emissions. However, after reaching a certain income threshold, the country begins to reduce pollution through investments in technology, regulation, and other measures. At the same time, the level of income inequality in a country can shift the EKC, delaying the onset of a decline in emissions.

To conduct an empirical test of the EKC hypothesis, panel data for Central Asian countries were used: gross domestic product (GDP) per capita and carbon dioxide (CO_2) emissions per capita, excluding emissions and removals from land use, land-use change and forestry (LULUCF), for the period 1990-2023. The information was obtained from the World Bank database.

The modelling of second-order polynomial regressions was carried out in MS Excel and R with the display of the trendline equation and the coefficient of determination R^2. To identify the possible nonlinear nature of the dependence, the value of the squared GDP per capita was included in the model.

The following formula is used to test the hypothesis of the EKC:

$$CO_2 = \beta_1 \times GDP^2 + \beta_2 \times GDP + \beta_0 + \varepsilon \quad (1)$$

where CO_2–CO_2 emissions per capita; GDP–GDP per capita.

If, as a result of the model estimation, the coefficient β_1 is negative (β_1<0) and the coefficient β_2 is positive (β_2>0), this indicates an inverted U-shaped curve and confirms the EKC hypothesis.

Previously, a comparative analysis of carbon intensity and economic development indicators for Central Asian countries was conducted based on data from the World Bank and The Atlas of Economic Complexity provided by the Harvard Growth Lab's.

The impact of income inequality on the level of emissions was analyzed using multiple linear regression, where the dependent variable is the level of CO_2 emissions per capita. The determinants are the Gini coefficient, indicators of urbanization (the share of the urban population), industrialization (the share of industry in GDP) and the Economic Complexity Index. The regression model was built using data from the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan and Harvard Growth Lab for the period 2000-2023.

The analysis was accompanied by a check of the multicollinearity of the variables.

4. DATA AND FINDINGS

4.1. Analysis of Structural Economic Indicators of Central Asian Countries

Before constructing econometric models aimed at testing the EKC hypothesis, we will examine the dynamics of GDP per capita and CO_2 emissions per capita in Central Asian countries for the period 1990-2023 (Graph 1). This will allow us to identify differences between the countries in terms of economic growth rates and levels of environmental pressure.

As can be seen from the graphs, Kazakhstan and Turkmenistan are leading among the Central Asian countries both in terms of GDP per capita and CO_2 emissions. Thus, in 2023 the carbon footprint of an average resident in Kazakhstan was 11.8 tons of CO_2/year, in Turkmenistan – 9 tons of CO_2/year, when the global average was 4.7 tons per person.

If we consider the overall dynamics of the indicators, it is only Kazakhstan shows the same trends for GDP and emissions, and only in the last 2 years have CO_2 emissions begun to gradually decrease with continued GDP growth. CO_2 emissions are strongly influenced by the structure of the economy, as well as the processes of industrialization and urbanization in the country.

Below is a table with indicators characterizing the process of urbanization (the share of the urban population of the total population of the country), industrialization (the share of industry in GDP), carbon intensity (the share of fossil fuels in total energy consumption) and economic complexity (Table 1).

The data indicate that the economies of Central Asian countries are predominantly focused on carbon-intensive industries, such as the oil and gas sector and the mining industry. In all countries, except Kyrgyzstan, the share of industry in GDP is more than 30%. This orientation inevitably leads to high levels of CO_2 emissions.

Graph 1: Dynamics of GDP and CO_2 emissions per capita in Central Asian countries

Source: Authors. Based on World Bank data (2023)

Table 1: Selected indicators of carbon intensity and economic development in Central Asian countries in 2023

Country	Urbanization, %	Industrialization, %	Carbon intensity*, %	Economic Complexity Index (ECI)	Ranking in the ECI among 145 countries
Kazakhstan	58.2	32.3	98.2	−0.44	89
Kyrgyz Republic	37.8	22.6	72.9	0.09	58
Tajikistan	28.2	34.7*	60.9	−0.98	118
Turkmenistan	54.0	39.3	100.0	−1.09	130
Uzbekistan	50.5	30.6	98.4	−0.23	70

Source: Authors. Based on data from the World Bank (2023) and Harvard Growth Lab's (2023). *World Bank data is only available for 2022

In addition to the level of industrialization, the high emissions of CO_2 per capita in Kazakhstan and Turkmenistan are driven by the following factors:

- A large share of fossil fuels in energy consumption (over 90%), indicating the predominance of carbon-intensive industries;
- High level of urbanization (58.2% in Kazakhstan and 54% in Turkmenistan) compared to other Central Asian countries;
- The dominant role of oil and gas in the structure of exports of goods (Table 2).

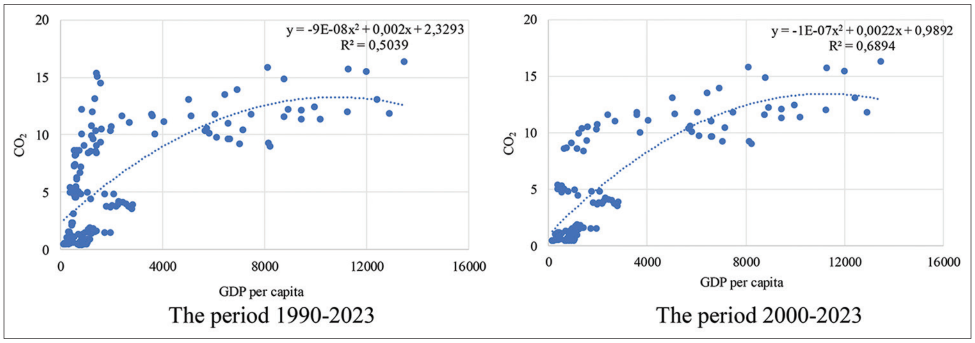
The analysis showed that the economies of the Central Asian countries are characterized by a large proportion of carbon-intensive industries, dependence on fossil fuels and resource-based export structure (oil, gas, gold, ores). Such features significantly influence CO_2 emission levels.

4.2. Environmental Kuznets Curve

In order to identify the relationship between the level of economic development and the level of environmental pollution in Central Asian countries, the EKC hypothesis was tested, suggesting a reduction in emissions upon reaching a certain income level. This approach allows us to determine where the countries of the Central Asian region are positioned: in the increasing part of the curve or already at the stage of improving the environmental situation.

The curve is constructed for two periods (Graph 2), one of which includes the transitional post-Soviet stage (1990-2023), and the second is a more stable period of economic development (2000-2023).

Graph 2: Environmental Kuznets curve for Central Asian countries



Source: Authors. Based on data from the World Bank

Table 2: Dominants in the export structure of Central Asian countries in 2023

Country	Exported goods		
Kazakhstan	Petroleum oils, crude (32.35%)	Gold (13.79%)	Uranium (3.61%)
Kyrgyz Republic	Gold (30.98%)	Precious metal ores (4.87%)	Coal (4.73%)
Tajikistan	Gold (19.26%)	Raw cotton (9.53%)	Antimony (8.57%)
Turkmenistan	Petroleum gases (69.65%)	Petroleum oils, refined (17.69%)	Nitrogenous fertilizers (3.12%)
Uzbekistan	Gold (31.83%)	Cotton yarn (5.02%)	Petroleum gases (1.92%)

Source: Authors. Based on data from the Harvard Growth Lab's (2023)

As a result of the analysis for two periods, the hypothesis of the environmental curve in the Central Asian countries was confirmed: as incomes grow, CO_2 emissions per capita first increase and then begin to decrease.

However, the coefficient of determination R^2 for 1990-2023 was 0.5039, which is less than the coefficient obtained for 2000-2023 (0.6894). This may be explained by the instability of the post-Soviet period associated with the transition from a planned economy to a market economy. An improvement in the quality of the model when analyzing data for 2000-2023 indicates that economic growth has been recovering in the Central Asian region since 2000. Therefore, next we will consider the results obtained for the period 2000-2023 (Table 3).

When analyzing the relationship between CO_2 emissions and GDP per capita for the selected period, a second-degree polynomial regression equation was obtained for the Central Asian countries:

$$y = -1E\text{-}07x^2 + 0{,}0022x + 0{,}9892 \quad (2)$$

The coefficient of determination $R^2 = 0.6894$, which indicates a relatively high degree of explanatory power of the model, both coefficients are statistically significant ($P < 0.001$). The curve has the shape of an inverted U, confirming the EKC hypothesis.

The calculating of the turning point in the EKC model allows for the identification of the level of economic development after which GDP growth is no longer accompanied by an increase in CO_2 emissions. It is carried out according to the following formula:

$$x = \frac{-\beta_2}{2 \times \beta_1} \quad (3)$$

Thus, by calculating, the maximum value of CO_2 emissions is achieved at an income level of about \$11,000 per capita. Among the Central Asian countries, only Kazakhstan crossed this point in 2022, which provides opportunities for sustainable growth. It was precisely in 2022–2023 that a downward trend in CO_2 emissions began in the country. The trend of reducing emissions with GDP growth can be maintained through modernization of industry, reducing dependence on carbon-intensive industries. The other countries are still below the turning point level, which highlights the need to implement environmental policies and structural diversification.

Table 3: Results of polynomial regression to test the EKC hypothesis in Central Asian countries

	Coefficients	The standard error	t-statistics	P-value
GDP	0.0022	0.0003	8.51	<0.001
GDP^2	-1.00×10^{-7}	2.30×10^{-8}	−4.33	<0.001

Source: Authors

4.3. The Impact of Income Inequality on CO_2 Emissions

The level of emissions may depend not only on income level, but also on income distribution. Income inequality can shift the EKC, delaying the decline in emissions. Therefore, it was decided to conduct an additional analysis by adding the Gini coefficient to the model, which allows for an assessment of the impact of income inequality on environmental pollution. It was not possible to carry out an analysis for Central Asia as a whole, instead, a country case for Kazakhstan was chosen, as the study was limited by the availability of data in other countries of the region: the full time series data on the Gini coefficient for 2000-2023 were available only for Kazakhstan.

The equation has the following form:

$$CO_2 = \beta_1 \times GDP^2 + \beta_2 \times GDP + \beta_3 \times Gini + \beta_0 + \varepsilon \quad (4)$$

However, when the Gini coefficient was included in the EKC model, a high correlation coefficient (−0.7) was found between

Table 4: Regression model results

Regression statistics					
Multiple R					0.80
R-square					0.65
Adjusted R-square					0.57
Standard error					1.42
Observations					24
Independent variable	**Coefficients**	**The standard error**	**t-statistics**	**P-value**	**Significance**
Gini	−48.830	35.439	−1.38	0.184	Not significant
Urban	0.607	0.759	0.80	0.434	Not significant
Industry	0.389	0.136	2.86	0.010	Significant
ECI	−3.613	2.734	−1.32	0.202	Not significant

Source: Authors

Table 5: Correlation matrix

	Gini	Urban	Industry	ECI	CO_2
Gini	1				
Urban	−0.57	1			
Industry	0.22	−0.57	1		
ECI	0.80	−0.30	0.02	1	
CO_2	−0.64	0.21	0.30	−0.68	1

Source: Authors

income level (GDP per capita) and inequality. This high correlation indicates the presence of multicollinearity between the variables and prevents an accurate assessment of the impact of income inequality on CO_2 emissions within the framework of the testing the EKC hypothesis.

In this regard, the study further explores the effect of income inequality on CO_2 emissions by constructing a regression model. For a more comprehensive analysis, indicators of economic complexity, urbanization, and industrialization are included in the model as additional factors. The equation of multiple linear regression has the form:

$$CO_2 = \beta_1 \times Gini + \beta_2 \times Urban + \beta_3 \times Industry + \beta_4 \times ECI + \beta_0 + \varepsilon \quad (5)$$

where CO_2–CO_2 emissions per capita; *Gini*–Gini coefficient; *Urban*–level of urbanization; *Industry*–level of industrialization; *ECI*–Economic Complexity Index.

The results of the regression model are presented in Table 4. The coefficient of determination R^2 was 0.65, which means that 65% of the variation in emissions is explained by the variables included in the model. The only statistically significant factor ($P = 0.010$) was the share of industry in GDP, with a positive coefficient (0.389). This confirms the thesis about the high degree of carbon intensity of the industrial sector and indicates the importance of its decarbonization.

The Gini coefficient turned out to be statistically insignificant ($P = 0.184$), which allows us to conclude that there is no direct link between income inequality and environmental pollution. Factors such as urbanization ($P = 0.434$) and the Economic Complexity Index ($P = 0.202$) also showed no significant impact.

The results have led to the fact that the impact of income inequality on CO_2 emissions should be examined through indirect channels, such as the structure of the economy and the level of urbanization.

To identify the factors that have the greatest impact on income inequality, an additional correlation analysis was conducted between the Gini coefficient and the variables included in the model (Table 5). This approach allows for the identification of indirect relationships that explain the absence of a direct effect of income inequality on emissions in the regression model.

The analysis showed a significant correlation between the Gini coefficient and the Economic Complexity Index ($r=0.80$), as well as with the level of urbanization ($r=-0.57$). Although urbanization and economic complexity did not show statistically significant effects on CO_2 emissions in the regression model, their strong correlation with income inequality suggests an indirect influence of inequality on emissions. The impact on the environment occurs through the structural characteristics of the economy: the structure of exports, the level of production diversification, technological capacity, consumption patterns, and others. This highlights the importance of incorporating socio-economic factors into the development of environmental policies.

5. CONCLUSION AND RECOMMENDATIONS

The problem of income inequality is becoming particularly relevant in the context of sustainable development, as it affects not only the socio-economic consequences, but also the environmental sustainability of countries. Income inequality can directly or indirectly affect greenhouse gas emissions. In the Central Asian countries, which are characterized by a focus on raw materials industries, high carbon intensity and uneven income distribution, the analysis of this relationship is of significant interest, especially against the background of international commitments to reduce emissions and achieve the SDGs.

The results of the study confirmed the hypothesis of the EKC for Central Asian countries: CO_2 emissions per capita initially increase with GDP growth, but after reaching a certain threshold they begin to decrease. When trying to include the Gini coefficient, the problem of multicollinearity was identified, which allowed us to conclude that there is no direct impact of income inequality on emissions. The impact of inequality occurs through factors such as economic complexity, urbanization, and the share of industry in GDP, which has confirmed the need for an integrated approach to environmental policymaking, taking into account socio-economic factors. Environmental policy should include measures to reduce inequality, diversify the economy, achieve balanced urbanization, and adopt environmentally friendly production technologies. This not only contributes to improving the quality of life and reducing the carbon footprint in countries, but also corresponds to global approaches to achieving the SDGs related to reducing inequality and combating climate change.

Moreover, when developing environmental policy, it is necessary to take into account not only overall income inequality, but also its structural components, in particular, functional inequality reflecting differences between labor income and capital income. In Central Asian countries, where carbon-intensive industries predominate (oil, gas, coal, and heavy industry), a significant share of profits is concentrated in the form of capital income. Investments are mainly directed to sectors with high emissions, which contributes to increased environmental pollution and complicates the transition to a more sustainable economy. Therefore, the effectiveness of the policy depends on taking into account the capital income and its impact on the structure of the economy.

Further research should focus on the analysis of the impact of income inequality on emissions through various factors (consumption patterns, infrastructure, energy efficiency, and others), as well as on the analysis of functional inequality. A comprehensive approach to the development of environmental justice mechanisms with a deeper analysis of the interconnections will help ensure more sustainable development and a more equitable distribution of benefits.

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