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FULL LENGTH ARTICLE

Trade Openness and Environmental Sustainability in Armenia: An Empirical Analysis of CO_2 Emissions (2001–2024)

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ABSTRACT

This paper examines the relationship between international trade openness, economic development, and environmental sustainability in Armenia during 2001–2024. The main objective is to identify the relationship between trade openness, GDP per capita, and carbon dioxide (CO_2) emissions. The study uses annual statistical data from the World Bank and applies descriptive statistical analysis, trend analysis, and multiple linear regression. The results demonstrate that Armenia experienced substantial growth in international trade and economic activity during the research period, accompanied by an overall increase in CO_2 emissions per capita. However, the dynamics of these indicators were not uniform. The regression analysis revealed a positive but statistically insignificant relationship between trade openness and CO_2 emissions. In contrast, GDP per capita demonstrated a positive and statistically significant association with carbon emissions. The regression model explained approximately 89.4% of the variation in the logarithm of CO_2 emissions. The findings suggest that the environmental consequences of Armenia's economic development cannot be explained by trade openness alone. The structure of foreign trade, energy consumption, and production characteristics may also play important roles. The research emphasizes the importance of combining international economic integration with improvements in energy efficiency, cleaner technologies, and sustainable production. The results provide a basis for further research on the relationship between international trade and environmental sustainability in small open economies.

Keywords: International Trade ▪ Trade Openness ▪ Environmental Sustainability ▪ CO_2 Emissions ▪ Economic Growth ▪ GDP per Capita ▪ Armenia ▪ Energy Efficiency ▪ Regression Analysis

1. INTRODUCTION

International trade is a key factor in a country's economic development. It provides access to foreign markets, underpins production, attracts investments, and provides opportunities for growth. It can also have negative environmental consequences, though, with increased production and transport requiring more energy and leading to higher CO_2 emissions. Trade can also benefit the environment by facilitating the diffusion of new technologies, better production techniques, and access to cleaner energy. The relationship between international trade and environmental sustainability is therefore a major issue for both developed and developing countries.

The environmental impact of international trade will largely depend on how a country produces its goods, how much energy it uses, its level of technological development, and the strength of its environmental regulations. A country whose economy is based on energy-intensive industry will see its emissions rise as trade increases. A country with a service-based economy and/or one that does not rely on energy-intensive production can grow its economy without necessarily increasing emissions. The difference is in the

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impact of trade in different countries. When looking at the environmental impact of trade, the particular circumstances of each country must be taken into account [1, 2].

This is particularly pertinent for Armenia. It is a small open economy with very limited domestic energy resources and is therefore heavily dependent on its international economic links. Since the early 2000s, Armenia's growth has been accompanied by changes in its trade, investment, production, and energy use. International trade has been a major factor in the growth of Armenian business and in enabling businesses to access new markets. Growth has also meant that the management of energy resources and the environmental impact of production and consumption have become increasingly important.

Armenia's dependence on imported energy adds an extra layer of economic and environmental difficulty. According to the World Bank, around 63% of Armenia's energy mix is imported natural gas [3]. The use of fossil fuels for electricity, heating, and transport all contribute to greenhouse gas emissions. The increasing use of renewables, particularly solar power, presents an opportunity to reduce energy dependence and mitigate the environmental impact. This is central to understanding the relationship between Armenia's economic growth, its trade, and its carbon emissions.

Another key point is that Armenia's foreign trade structure is in flux. Trade flows over 2022–2024 have been influenced by regional events and increased re-export activity. This has resulted in a higher volume of foreign trade being reported, which does not necessarily equate to an equivalent increase in domestic production. That is important for the environment, as emissions from Armenia's economy may not be increasing in line with the value of goods passing through the country.

This paper examines the relationship between international trade openness, economic growth, and CO_2 emissions in Armenia for the period 2001–2024. Trade openness is measured as the sum of exports and imports as a proportion of GDP. Economic growth is measured by GDP per capita in current US dollars. CO_2 emissions per capita are used as the environmental indicator. The paper uses statistical trends and a multiple regression model to determine whether changes in trade openness and income are associated with changes in CO_2 emissions. The results are intended to provide clarity on the environmental implications of Armenia's integration into the world economy.

1.1 Research Gap

Much work has been done on the relationship between international trade, economic growth, and pollution. The results are country-dependent, varying with the nature of each country's economy, its energy mix, and its level of development. Most of the work to date has been at the level of large economies or large groups of countries, while small energy-importing countries such as Armenia have largely been overlooked. Armenia is an interesting case because its foreign trade has grown in parallel with the evolution of its economy and energy use. There is a clear need for a study of the relationship between trade openness, income, and CO_2 emissions in Armenia using annual data.

1.2 Research Objective

The primary objective of the study is to examine the relationship between trade openness, economic growth, and CO_2 emissions in Armenia for 2001–2024. It examines the evolution of trade openness, GDP per capita, and CO_2 emissions per capita. A multiple linear regression model is employed to estimate the relationships between the variables. The study also investigates whether the relationship between trade openness and emissions is positive or negative after controlling for income. The findings are discussed in terms of their implications for Armenia's trade and environmental policy.

2. LITERATURE REVIEW

Economists have extensively examined the relationship between international trade and environmental protection. The fundamental question is whether increased trade leads to more pollution or less. Economic theory suggests both outcomes are possible. Trade can lead to greater production and greater consumption of resources, which in turn could lead to more pollution. It could also lead to greater efficiency and the use of cleaner technologies. The net effect on the environment will depend on which of these forces is dominant.

Grossman and Krueger examined the relationship between economic growth and environmental quality [4]. They found that pollution does not necessarily increase as income rises from low to high levels. For some environmental indicators, pollution increased in the early stages of development and then declined at higher income levels. This is the Environmental Kuznets Curve (EKC). The EKC suggests that pollution may rise in the early stages of development, but that at some point higher income can lead to better technology, better regulation, and hence better environmental quality. The EKC is not a universal rule, however, and the pattern varies by pollutant and country.

Antweiler et al. developed a theory to explain how international trade affects the environment [1]. They identified three effects: the scale effect (more pollution as economic activity increases), the composition effect (changes in what is produced, particularly if more polluting industries expand), and the technique effect (better techniques that lead to lower emissions per unit). Using global sulfur dioxide concentration data, they found that trade can lead to improvements in environmental quality. Their work demonstrates that trade openness is not necessarily detrimental to the environment.

Copeland and Taylor examined the links between international trade, economic growth, and the environment [2]. They point out that the way trade affects the environment is determined by differences in resources, types of production, and environmental regulations. A country may grow an industry in which it has an advantage even if that industry is energy-intensive. Trade can also enable a country to acquire cleaner technology and better equipment. Their work suggests that the environmental impact of trade depends not simply on trade volume but also on the policies and production methods of the countries involved.

Another explanation is the pollution haven hypothesis: firms in a country with strict environmental rules may move polluting production to a country with less stringent rules. Cole examined this hypothesis using trade data and a range of en-

vironmental indicators and found some evidence of pollution haven effects, though these were generally small compared with other factors [5]. There is therefore some evidence of pollution haven effects, but they are not the dominant factor.

Frankel and Rose examined whether international trade has a positive or negative effect on environmental quality [6]. Using cross-country data and a method that allows analysis of the relationship between trade openness and environmental quality, they found that trade was associated with lower levels of some air pollutants, though the evidence was less clear for other pollutants. The key point was that the environmental impact of trade is pollutant-specific. Findings for local air pollution do not necessarily hold for CO_2.

Stern was critical of the EKC, arguing that the relationship between higher income and a better environment was much weaker than previous studies had indicated [7]. Higher income does not necessarily equate to less pollution, particularly in an economy that remains reliant on fossil fuels. Technological change, environmental regulation, and economic structure are paramount. This is particularly the case in the developing world, where economic growth can lead to increased emissions in the absence of sufficiently developed clean-energy technologies.

A number of studies have examined the relationship between trade openness and carbon emissions in individual countries. Halicioglu studied CO_2 emissions, energy use, income, and foreign trade in Turkey for 1960–2005 [8]. Income was the most significant determinant of carbon emissions, followed by energy use and foreign trade. Stable long-term relationships existed among the variables. The study thus confirms the importance of income in the relationship between trade and pollution.

Jalil and Mahmud examined the relationship between CO_2 emissions, energy use, income, and foreign trade in China and found support for the Environmental Kuznets Curve during the period under consideration [9]. Income and energy use were the primary drivers of CO_2 emissions. Trade openness was positively related to emissions, though not statistically significant. Thus, there was no strong independent effect of trade openness on pollution once other economic factors were taken into account.

Sadorsky examined the link between energy use, GDP, and trade in seven South American countries and found a relationship between trade and energy use in both the short and long term [10]. The study did not estimate CO_2 emissions, though energy use is a major source of CO_2 emissions, but its results remain relevant to the environmental implications of trade. The study concludes that changes in trade have environmental implications through changes in energy demand and economic activity.

Armenia's situation is distinctive. The World Bank notes that the country's energy system remains heavily dependent on imported fossil fuels, while energy efficiency and renewable energy offer potential to reduce greenhouse gas emissions [3]. Foreign trade can provide Armenia with access to modern equipment and renewable technologies, though it may also increase domestic energy use through higher production and transport.

The literature makes clear that there is no single relationship between trade openness and pollution. Some studies have found environmental benefits, some have found more pollution, and some have found no relationship. These differences reflect countries' economic structures, energy systems, and environmental policies, as well as the indicators used. It is also vital to distinguish between domestic emissions and emissions embodied in internationally traded goods. Trade openness measures the volume of trade, not the pollution that trade generates.

For Armenia, the reviewed literature provides a foundation for examining the relationship between trade openness, GDP per capita, and CO_2 emissions using annual data from 2001 to 2024. The proposed regression model is a simple way of examining the statistical relationship between these variables. It cannot establish causality or explain all variation in CO_2 emissions, but it provides a basis for examining the relationship between Armenia's integration into the global economy and its environmental performance.

3. MATERIALS AND METHODS

This paper examines the relationship between trade openness, economic development, and CO_2 emissions in Armenia. It covers 2001–2024 and uses annual data. The objective is to determine whether changes in trade openness are related to changes in CO_2 emissions, controlling for the country's income level. The methodology combines descriptive statistics, trend analysis, correlation analysis, and multiple linear regression.

The statistics are from the World Bank's World Development Indicators. The three indicators are CO_2 emissions per capita, trade openness, and GDP per capita [11, 12, 13]. CO_2 emissions are measured in tonnes of CO_2 equivalent per capita, excluding emissions and removals from land use, land-use change, and forestry. Trade openness is the sum of exports and imports of goods and services as a percentage of GDP. GDP per capita is measured in current US dollars and serves as a measure of the country's income. All three indicators have consistent annual data for examining the relationship between international economic activity and the environment.

The research uses 24 annual observations. The dataset contains no missing values for the selected period. The first stage of the analysis examines changes in each indicator over time. Particular attention is paid to periods of economic growth, the 2009 economic slowdown, the COVID-19 period, and the expansion of Armenia's foreign trade after 2021. Descriptive statistics are used to identify average values, minimum and maximum observations, and changes between the beginning and end of the period.

The second stage applies multiple linear regression using the ordinary least squares (OLS) method. CO_2 emissions per capita are the dependent variable. Trade openness and GDP per capita are the independent variables. The regression model is:

$$\ln(\mathrm{CO}_{2,t}) = \beta_0 + \beta_1 \mathrm{Trade}_t + \beta_2 \ln(\mathrm{GDPpc}_t) + \varepsilon_t, \quad (1)$$

where:

- $\mathrm{CO}_{2,t}$ represents CO_2 emissions per capita in year t;
- Trade_t represents trade openness as a percentage of GDP;

- $GDPpc_t$ represents GDP per capita in current US dollars;
- β_0 is the constant term;
- β_1 and β_2 are the regression coefficients; and
- ε_t represents the error term.

Natural logarithms are taken of CO_2 emissions and GDP per capita. This enables the coefficient on GDP per capita to be interpreted as an elasticity. Trade openness is left in percentage points so its coefficient can be interpreted as the approximate percentage change in CO_2 emissions associated with a one-percentage-point increase in trade openness, holding GDP per capita constant.

The primary research hypothesis is that trade openness has a statistically significant relationship with CO_2 emissions in Armenia. The direction of the relationship is not specified in advance. Trade openness may lead to higher emissions through increased production, transport, and energy use. It may also lead to lower emissions through the adoption of cleaner technologies and more efficient equipment. Economic growth is expected to be positively related to emissions during periods when production and consumption remain reliant on fossil fuels.

The regression results are evaluated in terms of the estimated coefficients, their statistical significance, the R-squared, and the overall F-test. Residual autocorrelation is also checked via the Durbin–Watson statistic and the Breusch–Godfrey test. Given the relatively short annual time series, the results are treated as statistical associations rather than evidence of causality. Autocorrelation-robust standard errors are used to assess the reliability of the results.

An important caveat with respect to the GDP indicator is that GDP per capita is measured in current US dollars. Any change in the figure may therefore result from a combination of growth, price changes, and exchange-rate movements. Trade openness measures the value of international transactions as a proportion of GDP rather than the carbon emissions associated with traded goods, which would be preferable. These limitations are taken into account when interpreting the regression results.

4. RESULTS AND ANALYSIS

4.1 Dynamics of International Trade, Economic Development and CO_2 Emissions

The first stage of the research examines the evolution of Armenia's trade openness, GDP per capita, and CO_2 emissions from 2001 to 2024. All three indicators increased over the period, albeit non-uniformly. Armenia experienced periods of rapid economic expansion, economic stagnation, and major shifts in its international trade profile. The analysis examines whether growth in trade was matched by corresponding growth in environmental indicators.

Trade openness rose from 69.86% of GDP in 2001 to 150.06% in 2024, an increase of 80.20 percentage points or 114.8% relative to its initial value. The increase was not smooth. It declined between 2001 and 2008 to 54.54%, followed by a gradual recovery to 97.85% by 2019, indicating Armenia's growing integration into the international economy. In 2020, trade openness plunged to 70.12% during the global economic shock caused by the pandemic and other difficulties affecting Armenia's economic activity. It subsequently rebounded to 79.25% in 2021, exceeded 100% in 2022, and reached 150.06% in 2024.

Table 1. Dynamics of trade openness, GDP per capita and CO_2 emissions in Armenia, selected years

Year	Trade openness (% GDP)	GDP per capita (US$)	CO_2/capita (t CO_2e)
2001	69.86	660	1.145
2005	70.14	1,558	1.456
2008	54.54	3,778	1.883
2010	64.64	3,042	1.452
2015	71.68	3,513	1.872
2019	97.85	4,598	2.164
2020	70.12	4,269	2.351
2021	79.25	4,686	2.561
2022	103.88	6,572	2.672
2023	123.42	8,160	2.524
2024	150.06	8,557	2.499

Source: Compiled by the author based on World Bank data [11, 12, 13].

The largest movement in the indicator occurred during 2022–2024. Over those three years it was driven by changes in regional trade flows, growth in re-export activity, and an increase in the value of international transactions. This is significant because recorded trade volumes do not necessarily equate to an equivalent increase in domestic production. The indicator can rise substantially through the import of goods that are then re-exported, without the same environmental implications as goods produced in Armenia.

Figure 1 shows the evolution of trade openness over the period under review. There was a sharp increase in the latter part of the period, after 2021. The graph also indicates that Armenia's level of trade integration with the world, as measured by this indicator, has changed significantly over time.

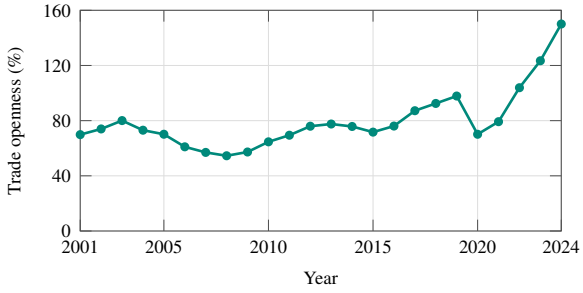


Figure 1. Dynamics of trade openness in Armenia, 2001–2024 (% of GDP)

Source: Compiled by the author based on World Bank, World Development Indicators [12].

GDP per capita also increased considerably, rising from around US$660 in 2001 to US$8,557 in 2024, a roughly 13-fold increase in nominal US-dollar terms. There were several periods of decline along the way. It fell from US$3,778 in 2008 to US$2,821 in 2009 as a result of the global financial

crisis's impact on the Armenian economy. There was another dip in 2020, with GDP per capita falling from US$4,598 to US$4,269 (Figure 2).

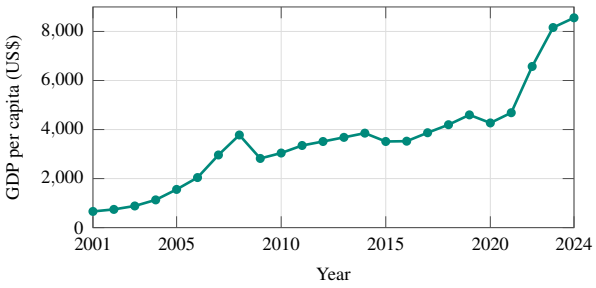


Figure 2. Dynamics of GDP per capita in Armenia, 2001–2024 (current US$)

Source: Compiled by the author based on World Bank, World Development Indicators [13].

After 2020, GDP per capita increased significantly, reaching US$6,572 in 2022 and US$8,557 in 2024. This reflects changes in Armenia's economic activity and income in US dollars. As the indicator is in current prices, its increase should not necessarily be interpreted as an increase in real output. It does, however, provide an indication of the general state of the country's economy over that period.

4.2 Changes in Carbon Dioxide Emissions

CO_2 emissions per capita rose from 1.145 tonnes in 2001 to 2.499 tonnes in 2024, a total increase of approximately 118.2%. The trajectory of emissions was linked to the evolution of economic activity, energy consumption, and other factors affecting domestic production and consumption (Figure 3).

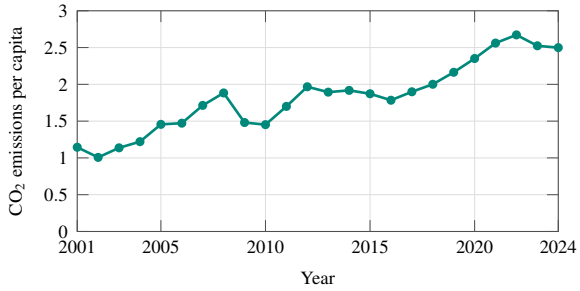


Figure 3. Dynamics of CO_2 emissions per capita in Armenia, 2001–2024 (tonnes CO_2e per capita)

Source: Compiled by the author based on World Bank, World Development Indicators [11].

During the early years of the research period, CO_2 emissions increased from 1.145 tonnes per capita in 2001 to 1.883 tonnes in 2008. In 2009, emissions declined to 1.481 tonnes. The decline coincided with a major reduction in economic activity. This pattern suggests that changes in production and consumption may be important for explaining the dynamics of Armenia's carbon emissions.

From 2010 to 2019, emissions generally rose, although with some variation. They peaked at 2.164 tonnes per capita in 2019. The trend then changed. In 2020, despite a reduction in trade openness, emissions rose to 2.351 tonnes per capita. They were 2.561 in 2021 and 2.672 in 2022.

The highest CO_2 emissions per capita in the dataset were recorded in 2022. They then dipped slightly in 2023 and 2024 to 2.524 and 2.499 tonnes, respectively. This was a reduction of around 6.5% between 2022 and 2024.

This is particularly interesting in light of trade openness. Trade openness increased from 103.88% to 150.06% of GDP between 2022 and 2024, while emissions per capita fell. Thus, the increase in recorded international trade was not matched by an equivalent increase in domestic emissions.

Figure 3 shows the dynamics of CO_2 emissions, with a general long-term upward trend, but the rate of increase in emissions is not the same as the rate of increase in trade openness. This implies that the relationship between the two may depend on other factors.

The drop in emissions after 2022 should not be taken as proof of any improvement in environmental efficiency. The data do not show whether this resulted from a change in energy use, the structure of the economy, how goods and services are produced, or another factor. A more thorough environmental assessment would require a wider range of indicators.

4.3 Descriptive Statistics

Descriptive statistical analysis provides further information about the distribution of the variables under consideration. Table 2 contains the minimum, maximum, mean, and standard deviation for the research period.

Table 2. Descriptive statistics, Armenia, 2001–2024

Statistic	CO_2 per capita (t CO_2e)	Trade openness (% GDP)	GDP per capita (US$)
Minimum	1.007	54.54	660
Maximum	2.672	150.06	8,557
Mean	1.824	79.68	3,581.83
Std. dev.	0.475	21.67	2,039.11

Source: Author's calculations based on 24 annual observations.

The average level of CO_2 emissions was approximately 1.824 tonnes per capita. The minimum value was observed in 2002, while the maximum was recorded in 2022. The difference between these observations reflects substantial changes in emissions during the period.

Average trade openness amounted to 79.68% of GDP. Its standard deviation of 21.67 percentage points indicates considerable variation, particularly influenced by rapid growth in trade openness during the final years of the research period.

GDP per capita had an average value of US$3,581.83. Its relatively large standard deviation reflects the considerable increase in nominal income over time. The differences in the dynamics of the three variables provide a basis for examining their statistical relationships.

4.4 Regression Analysis

To determine the relationship between international trade openness, economic development, and carbon dioxide emissions, a multiple linear regression model was estimated. The dependent variable is the natural logarithm of CO_2 emissions

per capita. The independent variables are trade openness and the natural logarithm of GDP per capita.

The estimated regression equation is:

$$\ln(CO_{2,t}) = -2.3818 + 0.000734\,\text{Trade}_t + 0.3615\ln(\text{GDPpc}_t). \quad (2)$$

The regression results are presented in Tables 3 and 4.

Table 3. OLS regression results: determinants of CO_2 emissions per capita in Armenia, 2001–2024

Statistic	Constant	Trade openness	ln(GDPpc)
Coefficient	−2.3818	0.000734	0.3615
Std. error	0.2318	0.001048	0.03297
t-statistic	−10.28	0.70	10.97
p-value	$p < 0.001$	0.491	$p < 0.001$

Source: Author's calculations using OLS.

Table 4. Model summary and diagnostic statistics

Model indicator	Value
Observations	24
R-squared	0.8942
Adjusted R-squared	0.8841
F-statistic	88.77
Overall model p-value	$p < 0.001$
Durbin–Watson statistic	0.8693

Source: Author's calculations using OLS.

The coefficient of trade openness is positive and equals 0.000734. According to this estimate, an increase in trade openness by 10 percentage points is associated with an approximately 0.74% increase in CO_2 emissions per capita, assuming GDP per capita remains unchanged. The coefficient is not significant: its p-value is 0.491, well above the 0.05 significance level. The regression therefore does not provide sufficient evidence that trade openness is statistically related to CO_2 emissions after accounting for GDP per capita.

This is in line with the descriptive analysis, which showed that changes in trade openness and emissions were not always in step. Armenia is a case in point, with a sharp rise in trade openness between 2022 and 2024 coupled with a very slight fall in emissions per capita.

The coefficient on GDP per capita is positive and highly significant. The estimated coefficient is 0.3615, implying that a 1% increase in GDP per capita is associated with a 0.36% increase in CO_2 emissions per capita, holding trade openness constant. The p-value is below 0.001.

The positive relationship between income and CO_2 emissions is consistent with the expectation that as economies grow, demand increases for energy, transport, and other activities associated with carbon emissions. The coefficient is for GDP per capita in current US dollars and therefore also reflects the impact of price and exchange-rate changes. It cannot be interpreted as the pure effect of real economic growth.

R^2 is 0.8942, so the two explanatory variables account for around 89.4% of the variation in the log of CO_2 emissions in the sample. Adjusted R^2 is 0.8841. The overall F-statistic is 88.77 ($p < 0.001$).

The indicators suggest that the regression has a fairly good fit in terms of explanatory power. The high R^2 must be treated with caution, however. Both GDP per capita and CO_2 emissions increased over a significant part of the period under review. Shared long-term trends can give rise to a strong statistical relationship even when the underlying economic mechanisms are more complicated.

The Durbin–Watson statistic is 0.8693, suggesting positive autocorrelation in the regression residuals. The Breusch–Godfrey test also confirms residual autocorrelation (p-value approximately 0.009). In other words, standard errors derived from the conventional OLS procedure may not be valid.

As an additional check, the regression was run using heteroskedasticity- and autocorrelation-consistent standard errors with one annual lag. The conclusion was the same. Trade openness was not significant ($p = 0.501$), and GDP per capita remained significant ($p < 0.001$).

Figure 4 compares actual CO_2 emissions per capita with the fitted values from the regression model. It captures the long-term rise in emissions, though there are some differences. For instance, in 2024 actual emissions were 2.499 tonnes per capita compared with a fitted value of 2.723 tonnes. This gap suggests that developments in emissions in the more recent period were not fully accounted for by the selected variables.

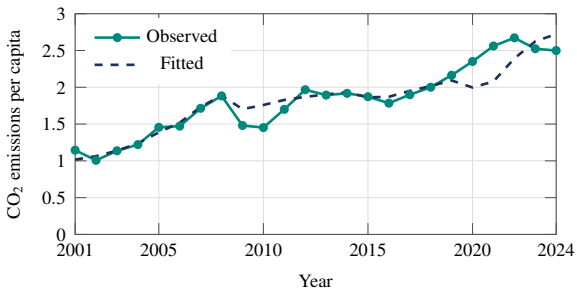


Figure 4. Actual and predicted CO_2 emissions per capita in Armenia, 2001–2024 (tonnes CO_2e per capita)

Source: Author's calculations based on World Bank, World Development Indicators (2025), using the estimated multiple linear regression model [11].

The regression results indicate that the relationship between economic development and CO_2 emissions was stronger than the relationship between trade openness and emissions in the estimated model. The results cannot be interpreted as evidence of a stable long-run relationship, however, given the small number of observations, the presence of time trends, and residual autocorrelation.

5. DISCUSSION

The regression shows a positive but statistically insignificant relationship between trade openness and CO_2 emissions after controlling for GDP per capita. This does not mean that trade openness has no effect on domestic carbon emissions. It means that the analysis does not provide sufficient evidence of a statistically significant relationship between the two variables. The results suggest that the general measure of trade

openness may not be a good indicator of the actual environmental effects of Armenia's engagement in the international market.

An important explanation may be connected with the structure of the country's foreign trade. International transactions involve goods and services with very different environmental characteristics. The export of domestically produced industrial goods generates emissions through production and energy use. Re-exports, on the other hand, can increase trade turnover without a corresponding increase in domestic manufacturing. The large increase in Armenia's trade openness over 2022–2024 makes this distinction particularly relevant. Therefore, the composition of foreign trade may be more important for environmental outcomes than the total value of exports and imports.

The positive and statistically significant coefficient on GDP per capita indicates that changes in the country's income were closely associated with changes in emissions over the period under study. This is consistent with the scale effect described by Antweiler et al. [1], in which greater economic activity is likely to create additional environmental pressure. It is also in line with Halicioglu's findings that income and energy consumption are important factors associated with emissions in Turkey [8]. However, the Armenian regression uses nominal income and does not establish a causal relationship.

These findings are also relevant for Armenia's environmental and international economic policy. Simply expanding foreign trade should not be seen as an environmental problem in itself. Trade can provide access to energy-efficient technologies, modern equipment, and renewable energy solutions, helping Armenia improve production efficiency while remaining competitive in international markets. At the same time, economic development requires greater attention to energy consumption, transport, and the environmental performance of domestic industries.

The main implication is that Armenia's trade expansion and environmental performance cannot be explained through a simple direct relationship. The environmental effects of international economic integration depend on what the country produces, what it trades, and how efficiently it uses energy. These factors should receive greater attention when developing trade and environmental policies.

6. CONCLUSION

This research examined the relationship between trade openness, economic development, and CO_2 emissions in Armenia during 2001–2024 using annual statistical data and multiple linear regression.

The results demonstrated that Armenia experienced substantial growth in international trade and economic activity during the research period. Trade openness increased from 69.86% of GDP in 2001 to 150.06% in 2024, while CO_2 emissions per capita increased from 1.145 to 2.499 tonnes. However, the dynamics of these indicators were not uniform, particularly during the final years of the research period.

The regression analysis identified a positive but statistically insignificant relationship between trade openness and CO_2 emissions. In contrast, GDP per capita demonstrated a positive and statistically significant association with emissions. The model explained approximately 89.4% of the variation in the logarithm of CO_2 emissions, although the presence of common time trends and residual autocorrelation requires careful interpretation of this result.

The findings suggest that international trade volumes alone cannot explain changes in Armenia's environmental performance. The structure of production, energy consumption, and the composition of foreign trade may also play important roles. For Armenia, the main challenge is to support international economic integration while improving the environmental efficiency of domestic economic activities.

6.1 Policy Recommendations

Based on the results of the research, several policy recommendations can be proposed for Armenia.

First, greater attention should be paid to the environmental characteristics of exported and imported products. Separating domestically produced exports from re-exports would improve the assessment of international trade's environmental impact. This distinction is particularly important given the substantial growth of re-export activities in recent years.

Second, government institutions should encourage businesses to introduce energy-efficient equipment and cleaner technologies, particularly in manufacturing and other energy-intensive activities. Such measures could reduce emissions associated with domestic production while supporting the competitiveness of Armenian products in foreign markets.

Third, Armenia should use international trade to expand access to renewable energy technologies. The import of solar equipment, modern energy systems, and energy-saving technologies could help reduce dependence on fossil fuels and improve environmental performance.

Finally, environmental and economic policies should be better coordinated. Economic development programmes could include measurable targets for energy efficiency and emissions reduction, allowing Armenia to pursue international economic integration alongside environmental protection.

6.2 Limitations of the Study and Directions for Further Research

The research has several limitations:

- The regression analysis covers only 24 annual observations and includes two explanatory variables. Other important factors, such as energy consumption, industrial structure, technological development, and environmental regulations, were not considered.
- GDP per capita was measured in current US dollars, meaning that changes in the indicator may also reflect inflation and exchange-rate movements.
- Trade openness does not distinguish between domestically produced exports and re-exported goods.
- The model also shows residual autocorrelation, while the variables display strong long-term trends. Consequently, the estimated relationships cannot be interpreted as causal effects or confirmed long-run relationships.

These limitations provide several directions for further research. One important direction is a more detailed analysis

of Armenia's foreign trade structure. Future studies could examine the relationship between CO_2 emissions and specific categories of traded products, particularly industrial goods, agricultural products, and energy resources.

Another direction concerns the role of energy consumption and renewable energy development. Including indicators such as fossil fuel consumption, the share of renewable energy in electricity generation, and energy intensity of GDP could help explain the factors associated with changes in emissions.

Further research could also examine the Environmental Kuznets Curve hypothesis for Armenia by introducing a non-linear relationship between income and CO_2 emissions. A longer dataset and appropriate time-series methods would be necessary to assess whether economic growth eventually becomes associated with lower emissions.

Finally, comparative research involving Armenia and other small open economies could provide a broader understanding of how international trade and environmental sustainability are connected under different economic conditions.

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