ECONOMIC SCIENCES

STATISTICAL ANALYSIS OF FACTORS AFFECTING ATMOSPHERIC POLLUTION AND CLIMATE CHANGE

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Abstract

Human interventions in ecological processes are different and generally have an intentional nature from the standpoint of achieving certain objectives. However, the ecological consequences of anthropogenic impacts can be both positive (reproduction of natural resources, land restoration, etc.) and negative. As a result of human activity, the gaseous composition of the atmosphere continues to change, the share of "greenhouse gases"[1] increases year by year and the thermal permeability decreases. Any change in the composition and properties of atmospheric air has a negative impact on the stability of ecosystems and human health. It is known that gases emitted into the atmosphere contribute to the increase of the Earth's temperature, and 50% of the greenhouse effect is caused by carbon monoxide, 18% by methane, and the share of chlorofluorocarbons is 15-20%. Obviously, all these aforementioned factors lead to additional warming of the Earth's surface and atmosphere.

Keywords. Atmospheric emissions, climate change, greenhouse gases, correlation-regression method.

In this day and age, climate change extends beyond being merely an environmental issue, evolving into a critical challenge for economic stability and sustainable development, as it significantly impacts various sectors of the economy. The consequences of climate change are the degradation of ecosystems, the reduction of natural resources and water resources, the scarcity of food, etc. [2, p. 453]. The Paris Agreement entered into force in the Republic of Armenia in April 2017, which is considered to be the first legally binding global agreement related to climate change, which establishes a plan to combat climate change. The goals of the Paris Agreement [6, Article 2] are to keep the increase in global average temperature well below 2°C above pre-industrial levels and to make efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this will significantly reduce the risks of climate change and influences.

Measurement, reporting and certification of greenhouse gas emissions (GHG) is an important tool in the fight against climate change. The latter is a system that enables us to observe the measures taken and the efforts made by the country in the direction of reducing emissions, which will also be in line with the principles used by other countries [7].

In 2023, the RA government adopted the long-term development strategy of RA with low emissions of greenhouse gases (until 2050) [8]. Despite the insignificant share of Armenia in the global emissions of anthropogenic greenhouse gases, 0.02%, the country actively participates in the international processes of combating climate change.

In RA, the national cadastre of greenhouse gases was developed for the period

1990-2019. The national inventory includes estimates of emissions/removals expressed in mass units and carbon in CO2 equivalents, applying the recommendations in the second ICMP Assessment Report Global warming potential (GWP) values [1, page 17].

[1] Such gases include carbon dioxide, methane, nitrogen oxides and water vapor.

Table 1:

Greenhouse gas emissions by materials (in CO2 equivalent), 1990-2019. [1]

	1990	2000	2005	2010	2016	2017	2018	2019
Carbon dioxide (CO2), thousand tons	21497.67	3154.52	4183.47	4600.50	5084.67	5606.64	5776.58	6213.52
Nitrogen suboxide (N2O), thousand tons	1035.40	697.50	827.7	778.10	1249.30	1057.10	1016.80	1271.00
Methane (CH4), thousand tons	3281.46	2342.34	2702.91	2841.93	3316.32	3252.27	2830.80	2693.46
Hydrofluorocarbons (HFCs), thousand tons	0.00	3.96	45.08	266.61	637.70	685.34	828.02	969.53
Sulfur hexafluoride (SF6), thousand tons	0.00	0.04	1.25	2.34	2.59	2.59	2.82	3.29
Total, thousand tons	**25814.53**	**6198.36**	**7760.41**	**8489.48**	**10290.58**	**10603.94**	**10455.02**	**11150.80**
Emissions per capita, tons	7.3	1.9	2.5	2.8	3.4	3.6	3.5	3.8

The data in Table 1 show that during 1990-2019, only greenhouse gas emissions were reduced by 56.8 percent, while in 2018 increased by 6.7 percent. Emissions per capita also decreased almost twice.

Table 2:

Greenhouse gas emissions by sectors (in CO2 equivalent), 1990-2019 [1]

	1990	2000	2005	2010	2016	2017	2018	2019
Energy	22719.35	4255.09	5252.55	5809.63	6623.41	7087.43	6822.29	7138.47
Industrial processes	630.91	148.60	349.46	319.62	157.10	264.01	343.34	312.50
F gases	0.00	4.00	46.33	268.94	640.30	687.93	830.85	972.82
Agriculture	2045.48	1276.84	1551.81	1524.05	2258.42	1941.92	1829.89	2098.31
Waste	418.79	513.83	560.26	567.24	611.35	622.65	628.65	628.7
Total emissions	**25814.53**	**6198.36**	**7760.41**	**8489.48**	**10290.58**	**10603.94**	**10455.02**	**11150.80**
Forestry and other land use	-736.89	-467.77	-523.74	-550.08	-487.87	-470.43	-455.23	-372.96
Net emissions	**25077.64**	**5730.59**	**7236.67**	**7939.40**	**9802.71**	**10133.51**	**9999.79**	**10777.84**

Analyzing greenhouse gas emissions by sector, it becomes clear that 64 percent of total emissions fall on the energy sector, and 29.4 percent on agriculture. As for the forestry sector, the emissions here are negative, that is, they absorb the greenhouse gases released into the atmosphere. It should be noted that, for example, the main sources of methane production are landfills, cattle (manure) and rice, and the generation of industrial waste is mainly related to the use of hot fossil fuels in thermal power plants, industrial enterprises, car engines and residential heating systems. During the burning of fossil fuels, compounds of sulfur, nitrogen, chlorine and several other elements enter the atmosphere.

Examining the dynamics of these indicators from 1990 to 2019, we notice that the total emissions of greenhouse gases have almost halved during this period, except for the agricultural sector, where emissions are at an almost stable level, and waste has increased by 50.1 percent.

The main source of atmospheric pollution, especially in large cities, is motor transport. It is calculated that burning 1 ton of gasoline produces 60 kg of carbon oxides and other toxic gases. 1000 cars emit 3 tons of CO_2 per day.

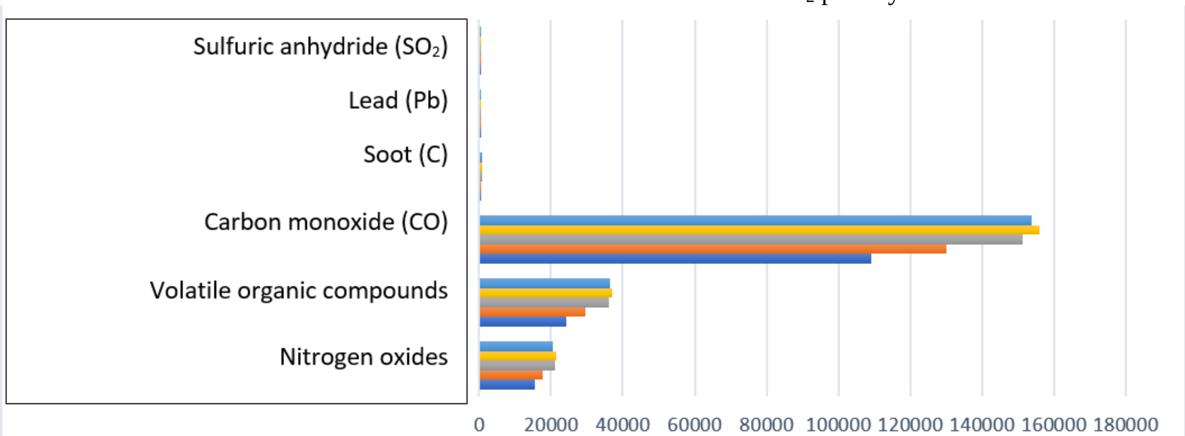

Figure 1: The amount of harmful substances released into the atmosphere from mobile sources, 2018-2022. (ton) [2, page 89]

It can be seen from Figure 1 that among the harmful substances released into the atmosphere from mobile sources, a significant part is carbon monoxide, which in 2022 made up 72.7% of total emissions or 153.8 thousand tons, volatile organic compounds - 36.5 thousand tons or 17.2%, nitrogen oxides - 20.6 thousand tons or 9.7% the volumes of carbon monoxide emissions increased by 44.6 thousand tons compared to 2018, but its share in total emissions decreased by 0.4 percentage points, and nitrogen oxides by 0.7 percentage poin

In recent years, government programs for the development of a new generation of vehicles have been implemented in all industrialized countries. For example, in the USA, until recently, the "Partnerships For A New Generation of Vehicles" cooperation program of the government and the automobile industry was operating, which is aimed at creating a prototype of an environmentally friendly, light passenger car with fuel consumption of no more than 3 liters per 100 km. 161 billion US dollars were spent for these purposes in 10 years. In the USA, according to the "Atmospheric Air Protection" law, it is prohibited to manufacture and operate motor vehicles, the amount of emissions of which exceeds the approved technical norms for harmful (polluting) emissions [4, p. 23].

The specific indicators of atmospheric emissions from stationary emission sources by marzes are presented in table 3, from which it becomes clear that according to the volume of emissions per inhabitant, Tavush, Syunik, Kotayk and Lori marzes stand out, which in 2022 exceeded twice the amount of the republic average level of emissions. As for the emissions per 1 km^2, the city of Yerevan, the regions of Kotayk, Tavush and Gegharkunik (without the surface of Lake Sevan) are the "leaders" in this indicator.

Table 3:

Specific indicators of atmospheric emissions from stationary emission sources by regions of the Republic of Armenia and the city of Yerevan, 2018-2022 [2, p. 88-89]

	Emissions									
	per capita, kg					per km^2, kg				
	2018	2019	2020	2021	2022	2018	2019	2020	2021	2022
City of Yerevan	12.7	12.5	13.2	14.1	14.9	61396.4	60681.6	64366.4	68742.4	72949.8
Aragatsotn	3.6	4.5	5.1	6.6	6.8	163.9	204.9	229.9	298.2	307.2
Ararat	10.5	10.5	12.4	13.9	14.8	1290.6	1284.4	1528.0	1711.3	1829.5
Armavir	6.9	6.4	7.3	7.9	8.3	1478.1	1363.0	1544.6	1689.8	1794.5
Gegharkunik	46.1	42.2	43.4	50.5	73.4	2592.1	2361.9	2424.0	2820.2	4115.0
Lori	162.2	44.4	54.6	58.9	66.9	9220.3	2504.4	3060.8	3286.7	3728.6
Kotayk	84.9	83.5	72.7	79.2	97.4	10213.9	10052.7	8746.0	9500.5	11851.9
Shirak	4.3	4.4	4.8	5.5	6.2	377.2	379.9	414.4	469.3	530.6
Syunik	76.0	76.2	75.4	79.2	97.4	2332.6	2325.2	2286.3	2376.8	2910.5
Vayots Dzor	5.0	4.9	5.8	7.0	6.6	107.6	102.5	120.7	145.9	135.2
Tavush	135.4	159.3	121.3	132.0	101.6	6166.2	7179.0	5427.2	5865.7	4500.1
Total RA	**38.4**	**30.3**	**29.1**	**31.7**	**35.6**	**4005.2**	**3151.9**	**3028.5**	**3296.9**	**3714.0**

From the comparative analysis of the data presented in Figure 2, it becomes evident that the annual emissions of harmful substances released into the atmosphere from motor vehicles significantly exceed those originating from stationary sources, with the notable exception of sulfur anhydride.

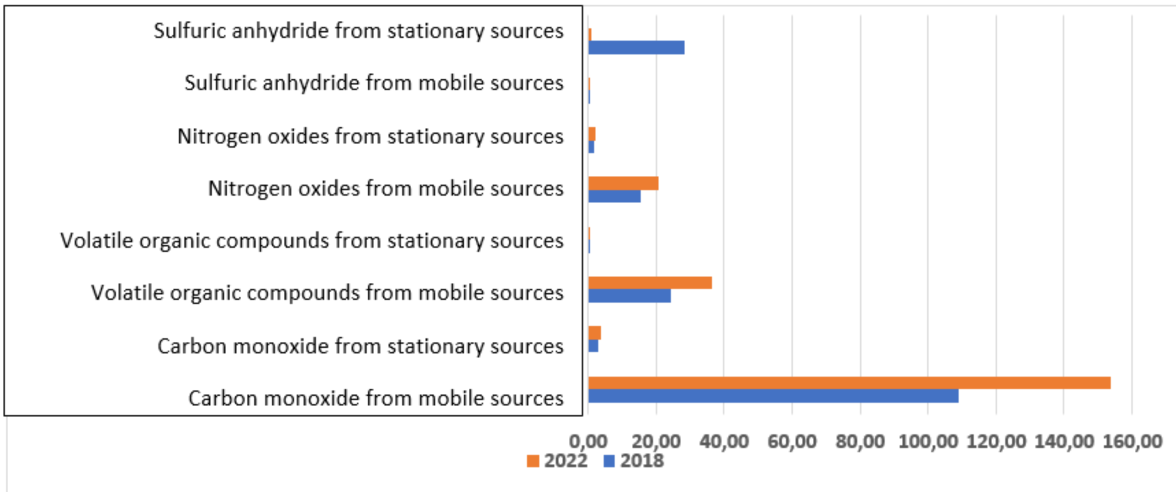

Figure 2: The main indicators of harmful substances released into the atmosphere from stationary and mobile emission sources in 2018 and 2022, thousand tons [2, p. 87, 89]

It should be noted that the significant decrease in the volume of the latter in 2022 is available perhaps due to the reduction of the total atmospheric emissions of the mining industry and exploitation of open pit mines (6.9 thousand tons in 2022 compared to 32.9 thousand tons in 2018).

Now let's evaluate the factors affecting climate changes using the correlation-regression method and build a statistical model using the SPSS software package.

Consider the following indicators as variables:

Y – the "Climate Change" sub-index, which is a component of the Environmental Security Index (EPI),

x_1- adjusted growth rates of carbon dioxide emissions (CDA),

x_2- adjusted growth rates of methane emissions (CHA),

x_3 - adjusted emission growth rate for F-gases (FGA),

x_4- adjusted emission growth rate for nitrogen oxide (NDA),

x_5- adjusted emission growth rates for black carbon (BCA),

x_6- projected GHG emissions in 2050 (GHN),

x_7- growth rates of carbon dioxide emissions from land cover (LCB)

x_8- greenhouse gas intensity growth rate (GIB)

x_9- greenhouse gas emissions per capita (GHP).

It is necessary to start the regression analysis with the study of the correlation matrix. First, based on the correlation matrix, we exclude those factors between which the pairwise correlation coefficients are higher than 0.8 (in absolute value), that is, between which there is multicollinearity. In this case, among the above-mentioned factors, there is multicollinearity between x_7 and x_4 factors (-0.83). Among the mentioned factors, factor x_4 has the closest dependence with the outcome variable Y, therefore we will remove factor x_7 from the model.

Table 4:

The main characteristics of the model

Model	R	R -squared	Standard Error	F	d.f.1	d.f 2	Sig.
1	.979[a]	.959	9.02831	112.539	9	43	.000

The coefficient of multiple correlation (R) is 0.979, which indicates a strong relationship between the observed variables, that is, the factors included in the model have a significant effect on the outcome variable. The coefficient of determination (R^2) shows that 95.9% of the variation of the outcome variable is caused by the variation of the factors included in the model. The value of the F-criterion indicates that the model is significant.

Table 5:

Linear regression model estimation results

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-31.227	6.927		-4.508	.000
x_1 –adjusted growth rates of carbon dioxide emissions (CDA),	.506	.076	.461	6.623	.000
x_2- adjusted growth rates of methane emissions (CHA),	.194	.039	.223	4.937	.000
x_3- adjusted emission growth rate for F-gases (FGA),	.016	.038	.014	.419	.677
x_4- adjusted emission growth rate for nitrogen oxide (NDA),	.017	.031	.021	.537	.594
x_5- adjusted emission growth rates for black carbon (BCA),	.023	.036	.030	.635	.529
x_6- projected emissions of greenhouse gases in 2050 (GHN),	.463	.032	.547	14.268	.000
x_7- growth rates of carbon dioxide emissions from land cover (LCB),	.099	.036	.100	2.755	.009
x_8- greenhouse gas intensity growth rate (GIB)	.018	.037	.021	.487	.629
x_9- greenhouse gas emissions per capita (GHP)	.033	.049	.026	.671	.506

And from the analysis of the results of the regression model [5, page 28], it becomes clear that the influence of the factors x_3, x_4, x_5, x_8, x_9 on the resulting variable is not significant[2], so in the model only significant factors (x_1,x_2, x_6) will be included.

As a result, the following regression equation will be obtained:

$$\hat{Y}= -31.227 + 0.506\, X_1 + 0.194 X_2 + 0.463 X_6$$

Thus, we come to the conclusion that the change in the growth rates of carbon dioxide and methane emissions will have a significant impact on the

[2] If the significance of the independent factor is less than 0.05, then the factor is significant.

"Climate Change" sub-index, which is quite logical, because as mentioned above, 50% of greenhouse gas emissions are accounted for by carbon monoxide and 18% - by methane.

The performed regression analysis can serve as a basis for environmental measures to reduce atmospheric emissions and prevent climate change.

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