E3S Web of Conferences **159**, 01006 (2020) https://doi.org/10.1051/e3sconf/202015901006
BTSES-2020

Mathematical modeling of Kazakhstan's CO_2 emissions and the role of environmental accounting

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Abstract. The global challenge of the 21st century is climate change. In many ways, these changes are exacerbated by the life of people. The factor that has the greatest negative impact on the environment is greenhouse gas emissions, which continue to grow. Kazakhstan is located at a considerable distance from the World Ocean, with an arid and sharply continental climate in most of the territory. According to data for 1976-2017, Kazakhstan has a faster growth rate of average annual air temperature than the global average. This further enhances the relevance of SDG(Sustainable Development Goals) 13 to the country. In this paper, we analyze the CO2 emissions of Kazakhstan for 2010-2018, and construct a function using linear regression equation. And also, we forecast carbon dioxide emissions for the next two years. In view of this, we will consider the importance of environmental accounting and its role in modern Kazakhstan.

1. Introduction

Despite the growing popularity of renewable energy sources and reduced emissions from coal, gas and oil consumption are growing in the world. This makes the chances of avoiding climate catastrophe increasingly illusive. In 2018, humanity released 37 billion tons of carbon dioxide into the atmosphere [1,2,3,4]. Emissions have been rising for three consecutive years and have reached record levels that further distance us from averting climate catastrophe. The only positive moment is that the intensity of this indicator has slightly decreased [5].

The 195 countries that have signed the Paris Agreement have committed themselves to reduce greenhouse gas emissions in order to keep global temperature growth well below 2 ° C compared to the pre-industrial period [6, 15]. Tracking the concentration of carbon dioxide - the main catalyst for global warming released into the Earth's atmosphere as a result of human activities, is necessary in order to understand whether we are on track to prevent climate change[12, 7, 10]. However, the gas that comes from many different sources continues to accumulate in the atmosphere, challenging scientists and governments.

The burning of fossil fuels, cement production and land-use change are the main human activities that lead to a sharp increase in CO2 emissions[16]. As the Secretary-general of the World Meteorological Organization PetteriTaalas noted: "It is worth recalling that the last time the Earth experienced a comparable concentration of CO2 concentration was 3-5 million years ago. Back then, the temperature was 2–3 degrees Celsius (°C) warmer, sea level was 10–20 meters higher than now[8]."

Although oceans and terrestrial vegetation absorb a significant amount of carbon dioxide, the rest of it accumulates in the atmosphere. Moreover, natural sinks are not able to cope

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with the increasing intensity of emissions, and the efforts of the world community to neutralize CO2 are clearly insufficient.

The first conclusions regarding how faithfully countries fulfill their commitments to reduce greenhouse gases will be made in 2023. Information on the amount of anthropogenic CO2 emissions and their future fate will help develop effective climate policies. “This is a huge task that is becoming increasingly difficult,” said Dr. Great Janssens-Maenhout, Chair of the European Commission's CO2 Monitoring Task Group. - 195 countries must provide emission data using the same methodologies. Today they do not have the same resources [11].”

Currently, countries are analyzing emissions by taking an inventory of emissions from fossil fuel combustion[4]. However, not all countries have the same opportunities. “Only developed countries are able to provide accurate, transparent, complete and consistent data in the form of greenhouse gas emissions inventories. However, according to the transparency principles established by the Paris Agreement, developing countries must also do this every two years, said Lucia Perugini, project manager at the Mediterranean Center for Climate Change. “Many developing countries do not have the data necessary to calculate greenhouse gas emissions, namely, information regarding the nature, scale, place and time of human activity, as well as the volume of emissions associated with each type.”

In reality, each phenomenon is a consequence of not only one factor, but several, even a complex of them. Their combined action can have different effects. If part of the causes has the opposite direction with respect to the object of action, then their combined effect on the effect is weakened or even nullified. Even a situation may arise when a well-defined, real-life cause has no obvious effect. This means that along with this reason, there is another, absorbing effect of the former. So, it is necessary to investigate the effect of various causes, i.e., to investigate the dependence of one phenomenon on a number of other phenomena that cause the first.

It is completely obvious that not all causes and factors, to some extent affecting the phenomenon under study, can be investigated. We are forced to confine ourselves to only significant reasons.

The increase in greenhouse gas emissions, climate change and the globalization of the economy have led to the development of environmental accounting, which is currently comparable in importance to other types of accounting. The importance of environmental information in making economic decisions has grown in view of the development of the concept of sustainable development of corporations. However, environmental accounting is still an area where there are many theoretical, organizational and methodological questions that need to be answered. The lack of concreteness and lack of unity is not even in the issue of the necessity of environmental accounting, but the place of environmental accounting in the system of other types of accounting, which is one of the main reasons for the debate of scientists and practitioners.

The term eco-efficiency refers to the reduction of the environmental impact of an enterprise. Enterprises that are eco-efficient care for the environment, but at the same time are highly profitable companies.[2] However, eco-efficiency is not possible without environmental accounting and reporting. It is important for companies to have information about the environmental impact of their actions, on possible environmental activities and their costs.

The need for environmental accounting is dictated by the following circumstances:

First, enterprise accounts should reflect its environmental impact and show the impact of costs, risks, obligations related to environmental activities on the financial situation of the enterprise.

Secondly, directly interested individuals need to have information to make economic decisions. For example, investors are interested in environmental information for investment decisions. It is also very important to take into account ongoing environmental activities, which shows the interest of the enterprise in ecology.

Thirdly, it is necessary to correctly identify and apportion the costs of environmental activities. Investors are interested in the correct assessment of these costs, so that in the future their decisions are based on real costs and benefits. This fact is also the subject of management accounting, as managers need to responsibly approach the process of identifying and sharing costs associated with environmental activities.

Fourthly, in today's very competitive economy, it is very important for enterprises to show themselves on the good side to attract customers. Services and products that are preferable from the environmental side, at the moment, are popular. Therefore, it is important for enterprises to show themselves to be an environmentalist.

Fifthly, companies will increase their eco-efficiency through environmental accounting. Today, the less the company's impact on the environment, the greater the chance of increasing profitability.

Environmental accounting is a dynamically developing area, which now also includes environmental audit. The reporting of large companies is now not only about financial indicators, but also about the environmental impact of their actions, and activities related to this. At the moment, the international community is analyzing the environmental accounting systems of different countries in order to develop guidelines for national standardization bodies.

This study presents CO2 emissions of Kazakhstan from 2010 to 2018. Based on a mathematical modelling of carbon dioxide emissions, we further estimate its future amountsin 2019 and 2020 using three different methods of extrapolative forecasting. Moreover, we will discuss how environmental accounting can help in the final aim of further emission controls.

2. Methodology

2.1. Extrapolative forecasting

Extrapolative forecasting is a method of scientific research and prediction, which is based on assuming that past and present trends, patterns, relationships will continue in the future development of the forecasting object. There are three methods of extrapolative forecasting: the moving average method, the method of exponential smoothing, the least squares method.

2.1.1.The least squares method

Minimizing the sum of the squared errors is the essence of the least squared method. Finding the calculated values with the regression equation, we try to smaller the distance between the actual and the calculated values. The smaller the distance, the more accurate is the forecasting results.

The working formula of the least squares method:

$$y_{t+1} = \alpha x + \beta$$

Where $t+1$ is the forecast period; y_{t+1} - predicted indicator; α and β are the coefficients; x is the symbol of time.

The calculation of the coefficients α and β is carried out according to the following formulas:

$$\alpha = \frac{\sum_{i=1}^{n}(y_a \cdot x) + (\sum_{i=1}^{n} x \cdot \sum_{i=1}^{n} y_a))/n}{\sum_{i=1}^{n} x^2 - (\sum_{i=1}^{n} x)^2/n}$$

$$\beta = \frac{\sum_{i=1}^{n} y_a}{n} - \frac{\alpha \cdot \sum_{i=1}^{n} x}{n}$$

where, y_a - the actual values; n is the number of levels of the time series.

Analysis of the trend is determined by considering time as an independent variable, and the levels of the series act as a function of this independent variable.

To calculate the Relative Approximate Error (RAE), we use the following formula:

$$\varepsilon = \frac{1}{n} \cdot \sum_{i=1}^{n} \left[\frac{|y_a - y_c|}{y_a} \cdot 100\%\right]$$

2.1.2.The moving averages method

The moving averages method is one of the well-known methods of smoothing time series. Using this method, one can eliminate random fluctuations and obtain values corresponding to the influence of the main factors.

This method is used for short-term forecasting. His working formula:

$$y_{t+1} = m_{t-1} + \frac{1}{n} \cdot (y_t - y_{t-1})$$

where $t + 1$ is the forecast period; t is the period preceding the forecast period (year, month, etc.); y_{t+1} - predicted indicator; m_{t-1} - moving average for two periods before the forecast; n is the number of levels included in the smoothing interval; y_t is the actual value of the investigated phenomenon for the previous period; y_{t-1} - the actual value of the investigated phenomenon for two periods preceding the forecast.

2.1.3.The exponential smoothing method

The exponential smoothing method is most effective in developing medium-term forecasts. It is acceptable when predicting only one period ahead. Its main advantages are the simplicity of the calculation procedure and the ability to take into account the weights of the initial information. The working formula of the method of exponential smoothing:

$$U_{t+1} = \alpha \cdot y_t + (1 - \alpha) \cdot U_t$$

where t is the period preceding the forecast; $t + 1$ is the forecast period; U_{t+1}- the predicted indicator; α is the smoothing parameter; y_t is the actual value of the studied indicator for the period preceding the forecast; U_t is the exponentially weighted average for the period preceding the forecast.

When forecasting with this method, two difficulties arise:

- the choice of the value of the smoothing parameter α;
- determination of the initial value of U_0.

There is no exact method for choosing the optimal value of the smoothing parameter α. In some cases, the author of this method, Professor Brown, proposed determining the value of α based on the length of the smoothing interval. Moreover, α is calculated by the formula:

$$\alpha = \frac{2}{n + 1}$$

where n is the number of observations in the smoothing interval.

2.2. Data source

2.2.1. Energy activity data

Accounting for Kazakhstan's carbon dioxide emission is based on ENERDATA's Energy Statistical Yearbook2019.All data is compiled according to a tested process, enhanced over the years to provide the most up-to-date information.Primary energy data comes from the International Energy Agency (IEA).Data is completed with statistics from regional organisations (Eurostat, Olade, ADB, OPEC, AUPTDE, etc) or specialised institutions (CEDIGAZ, EurObserv'ER, etc.), as well as from data from national sources (national statistics or data specially prepared by local correspondents from more than 100 partners in over 60 countries). The methodology and definitions used by ENERDATA are the same as that of IEA and Eurostat.

3. Results and discussion

3.1. Basic energy and socio-economic status in Kazakhstan

In terms of reserves and diversity of many minerals, Kazakhstan is one of the richest regions in the world. Minerals are represented by almost all the elements of the periodic table. The republic ranks first in the world in explored reserves of zinc, tungsten and barite, second in reserves of silver, lead and chromite, third in copper and fluorite, fourth in molybdenum, sixth in gold. Among the CIS countries, Kazakhstan accounts for 90% of the total reserves of chromites, 60% of wolfram, 50% of lead, 40% of zinc and copper, 30% of bauxite, 25% of phosphate rock, 15% of iron ore, more than 10% of coal. Significant oil and gas reserves are concentrated in the Western region, allowing Kazakhstan to be ranked among the ten largest oil producing states in the world, which have a significant impact on the formation of the world energy market[3, 19].

Currently, the country is competitive on the international market in the field of extraction and export of fuel, energy and metals. According to the latest estimates, the total oil and gas reserves in Kazakhstan are 23 billion tons, of which about 13 billion tons are concentrated in the Caspian shelf.

Kazakhstan is one of the ten countries - leading producers and exporters of coal in the world market, its share in the world coal production is about 2%, and in the world coal export - almost 5%. The country is developing about 30 major coal basins, most of which are located in northern and central Kazakhstan. The most affordable and cheapest coal in the CIS is mined in the Karaganda region [21,22].

According to scientists from leading countries of the world, Kazakhstan ranks sixth in the world in reserves of natural resources, although it still cannot use this advantage with the greatest effect for itself. According to some scientists, the explored bowels of Kazakhstan are estimated at about 10 trillion US dollars[19, 23].

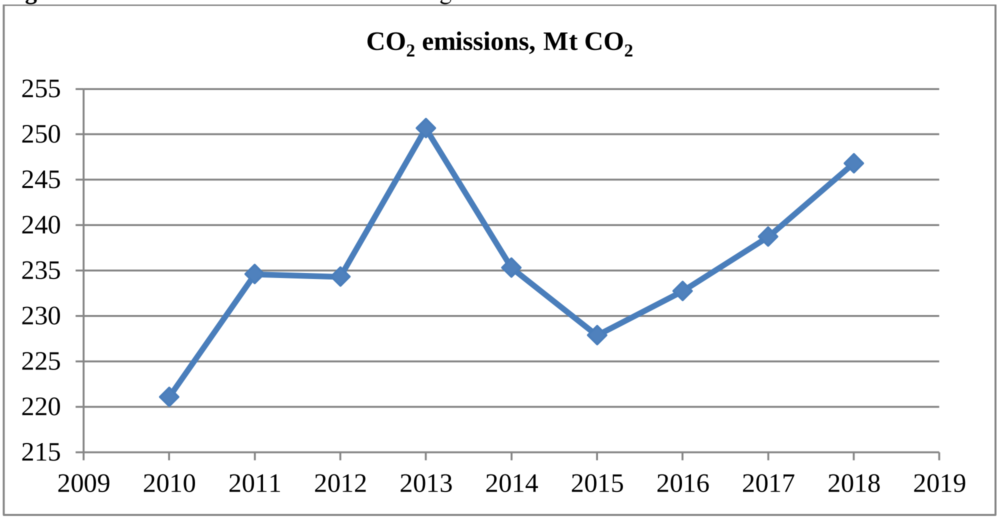
Energy reservation directly determines the demand and supply of energy structure, and subsequently affects emissions. Fossil fuel combustion is the main source of CO2 emissions in Kazakhstan [4], and the structure of fuel production and consumption reflects data on the level of activity for emissions. According to Kazakhstan's official statistics, from 2012 to 2016, domestic energy supply maintains a stable level (286,645-301,112 106 tons of standard fuel) and corresponds to the majority of domestic and export demand (75.95% -87.67%), while imports and other consumption are only small share of total(3.24% -5.37%). In the total volume of primary energy supply, the share of coal is 40%, while oil and gas separately account for almost 30%, but in general, the final consumption of coal exceeds two other elements of primary energymore than 20% [14]. From this point of view, coal prevails in Kazakhstan's consumption structure, and countries with a similar energy structure usually face serious emissionsreduction tasks[20].

3.2. Kazakhstan CO2 emission accounts 2010–2018

Fig. 1 illustrates Kazakhstan's CO2 emissions during 2010 and 2018, where we clearly see the increasing trend of carbon dioxide emissions with a small deviation in 2014 and 2015. Using the least squares method, we created the linear regression equation to further forecast future carbon volumes.

According to the Paris Agreement, Kazakhstan is committed to fulfilling its unconditional target of a 15% reduction in greenhouse gas (GHG) emissions by 31 December 2030 (compared to 1990) and a conditional target of a 25% reduction in greenhouse gas emissions by 31 December 2030 (compared with 1990) [18, 13].

Figure 1. Kazakhstan's CO2 emissions during 2010-2018



3.3. Assessment of future CO_2 emissions using the Least Squares Method

$$y = 1.4887\,x - 2762.3947$$

	y_a	x	x^2	$y_a^{\ 2}$	$y_a * x$	$y_c = 1.4887\,x - 2762.3947$	$\frac{\lvert y_a - y_c \rvert}{y_a} \cdot 100\%$
	221.07	2010	4040100	48871.9449	444350.7	229.8923	4
	234.59	2011	4044121	55032.4681	471760.49	231.381	1.37
	234.31	2012	4048144	54901.1761	471431.72	232.8697	0.61
	250.65	2013	4052169	62825.4225	504558.45	234.3584	6.5
	235.3	2014	4056196	55366.09	473894.2	235.8471	0.23
	227.87	2015	4060225	51924.7369	459158.05	237.3358	4.15
	232.72	2016	4064256	54158.5984	469163.52	238.8245	2.62
	238.71	2017	4068289	56982.4641	481478.07	240.3132	0.67
	246.8	2018	4072324	60910.24	498042.4	241.8019	2.03
Total:	2122.02	18126	36505824	500973.141	4273837.6	2122.6239	22.18

Table 1. The least squares method

$$\alpha = \frac{4273837.6 + (18126 \cdot 2122.02)/9}{36505824 - 18126^2/9} = 1.4887$$

$$\beta = \frac{2122.02}{9} - \frac{1.4887 \cdot 18126}{9} = -2762.3947$$

$$\varepsilon = \frac{1}{9} \cdot 22.18\% = 2.46\% < 10\%$$

Calculating Relative Approximation Error, we can state that the forecast accuracy is high as it is below 10%. The accuracy of the first method is 2.46%, which we further will compare with other RAEs of other methods.
Using the linear regression equation, we calculated the forecasting volumes of CO_2 emissions of 2019 and 2020.

y

3.4. Assessment of future CO2 emissions using the Moving Average Method

Table 2. The moving average method

x	y_a	*Middle average, m*	
2010	221.07	-	-
2011	234.59	229.99	1.96
2012	234.31	239.85	2.36
2013	250.65	240.1	4.21
2014	235.3	237.94	1.12
2015	227.87	231.96	1.79
2016	232.72	233.1	0.16
2017	238.71	239.41	0.29
2018	246.8	-	-
		Total:	11.89
2019	242.11		
2020	240.97		

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In Table 2, the moving average mstands for y calculated or y_c. RAE equals to 1.69%, which means that the forecast accuracy is high, and it is also relatively lower than the least squares method's value.

3.5. Assessment of future CO2 emissions using the Exponential Smoothing method

First, we calculate the smoothing parameter α using our number of observations.

Second, two methods arise when we choose U_0. First method is by calculating the arithmetic mean of all the observation values. Second method is by choosing U_1 as U_0.

$$U_0 = \frac{221.07+234.59+234.31+250.65+235.3+227.87+232.72+238.71+246.8}{9} = 235.78 \text{ – first method}$$
$$U_0 = 221.07 \text{ – second method}$$

Calculating U_{2011} using first method:
$$U_{2011} = 221.07 * 0.2 + (1 - 0.2) * 235.78 = 232.84$$
Calculating U_{2011} using second method:
$$U_{2011} = 221.07 * 0.2 + (1 - 0.2) * 221.07 = 221.07$$
Calculating U_{2019} using first method:
$$U_{2019} = 246.8 * 0.2 + (1 - 0.2) * 235.254 = 237.56$$
Calculating U_{2019} using second method:
$$U_{2019} = 246.8 * 0.2 + (1 - 0.2) * 232.782 = 235.58$$

Table 3. The exponential smoothing method

y_a	y_c (first method)	y_c (second method)	$\frac{\lvert y_a - y_c \rvert}{y_a} \cdot 100\%$	
221.07	235.78	221.07	6.65	0
234.59	232.84	221.07	0.746	5.76
234.31	233.19	223.77	0.48	4.49
250.65	233.41	225.876	6.88	9.88
235.3	236.86	230.83	0.66	1.89
227.87	236.55	231.72	3.8	1.69
232.72	234.81	230.95	0.87	0.76
238.71	234.39	231.30	1.81	3.1
246.8	235.254	232.782	4.67	5.67
		Total:	26.566	33.24
Forecast for 2019	237.56	235.58		

$$\varepsilon_1 = \frac{1}{9} * 26.566\% = 2.95\% < 10\%$$
$$\varepsilon_2 = \frac{1}{9} * 33.24\% = 3.69\% < 10\%$$

We have two RAEs in the exponential smoothing method and we calculated each. The third method is known for its short-term use, so we could not forecast for 2020. The Relative approximate errors are high as well as two other methods', but it is comparatively higher than them.

In the first and third cases, the forecast accuracy is high, since the relative error is less than 10%. But the moving averages method allowed to obtain more reliable results (forecast for 2019–242.11 Mt CO_2, forecast for 2020 – 240.97 Mt CO_2), since the relative error when using this method is the smallest –1.69%.

4. Conclusion

Environmental accounting is increasing in itsrelevance due to the increase ofecological problems, economic, social and high technology developments. Environmental accounting is a tangible tool in the application of sustainable development and it is also a requirement of social responsibility of the enterprises.

Globalization has led us to a very rapid development, literally, of everything. It became easier for countries to cooperate, we began to produce more, consume more, but as they say, the coin has two sides. With the increase in production capacity, we have also increased greenhouse gas emissions, which have led and is still leading our Earth into a desperate state. CO2 emissions are increasing every year, and countries' promises to minimize it seem unfulfillable. Using Kazakhstan as an example, we predicted future CO2 emissions, where it can be seen that emissions will continue to grow. The introduction of a system that will monitor and calculate CO2 emissions is not only a necessity, but a requirement. A requirement for the Earth to have a future.

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