Economic and mathematical modelling of sustainable extraction of natural resources

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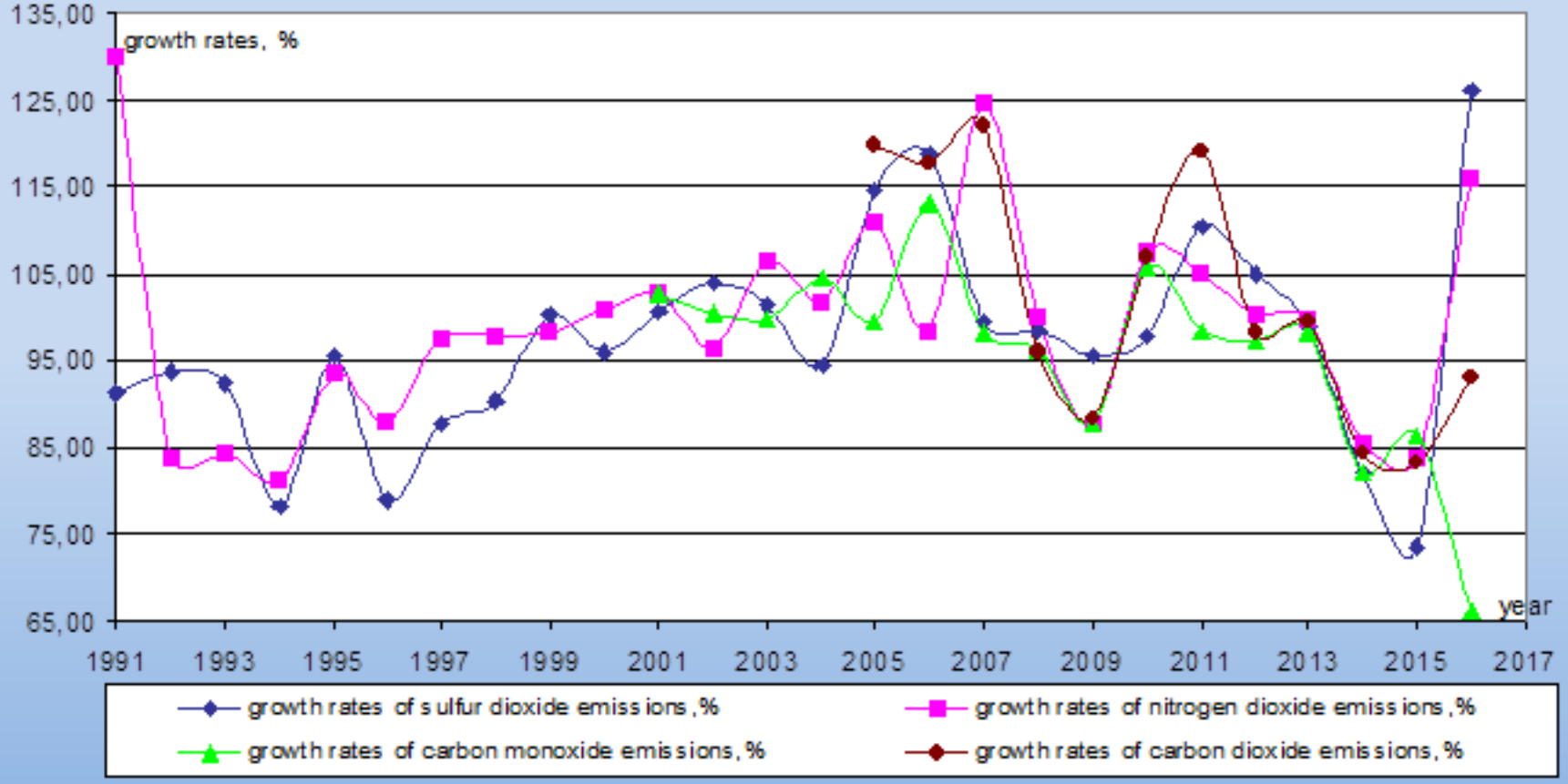
Ukraine is one of the world leaders by the explored reserves of coal, iron, manganese, titanium and zirconium ores, as well as graphite, kaolin, potassium salts, sulfur, refractory clays, and facing stone. For instance, it has 7.5% of the world coal reserves, 15% of iron ore reserves. Ukraine extracts significant amounts of hard coal (1.5% of the world production) and commercial iron ore (4.5%). The pace and scale of its own mineral resources base reproduction do not meet the country`s needs. The lack of funds reduced geologic exploration by 3-4 times. Therefore, since 1994, the explored reserves growth of most important minerals does not offset their extraction. Therefore, there is a need to form the system of rational minerals extraction. That is why, in our opinion, it is worth to model and forecast their production in the long run.

Figure 1. Dynamics of growth rates of pollutant emissions during 1991 – 2016



Economic and statistical modelling of the dynamics of pollutant emissions` determinants in Ukraine for the following substances: sulfur dioxide, nitrogen dioxide, carbon monoxide and carbon dioxide have been made. Data on the sum of emissions during 1991 - 2017 and their growth rates have been used. The model is to determine the safe limits of changes in emissions and their growth rates. The approach is explained by the fact that during the studied period emissions fluctuated within certain limits, but the environmental disaster did not happen. These data can be used as a guide for the target (expected) emission values (minimum emission degree) and critical ones (maximum emission degree).

Figure 2. *Relative and cumulative frequencies of sulfur dioxide emissions during 1991-2016*

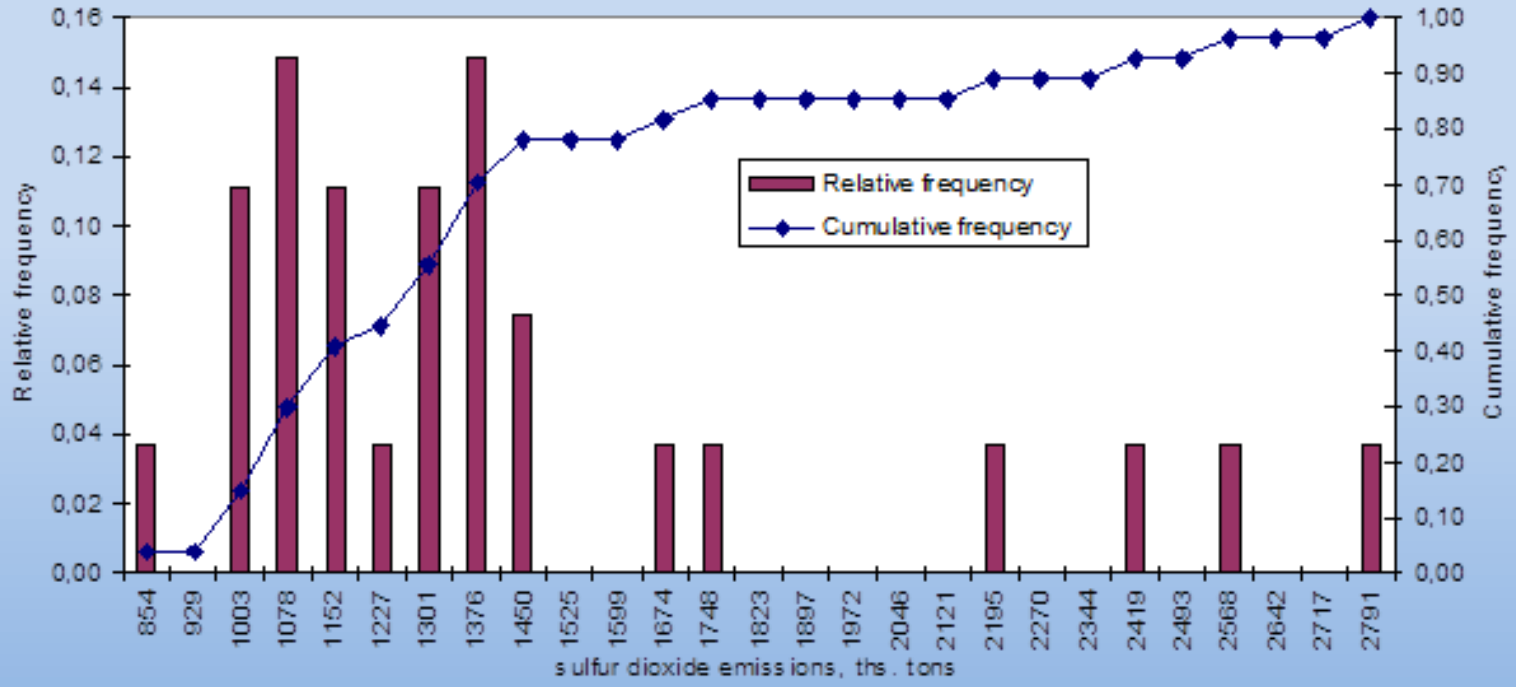


Figure 3. *Relative and cumulative frequencies of nitrogen dioxide emissions during 1991-2016*

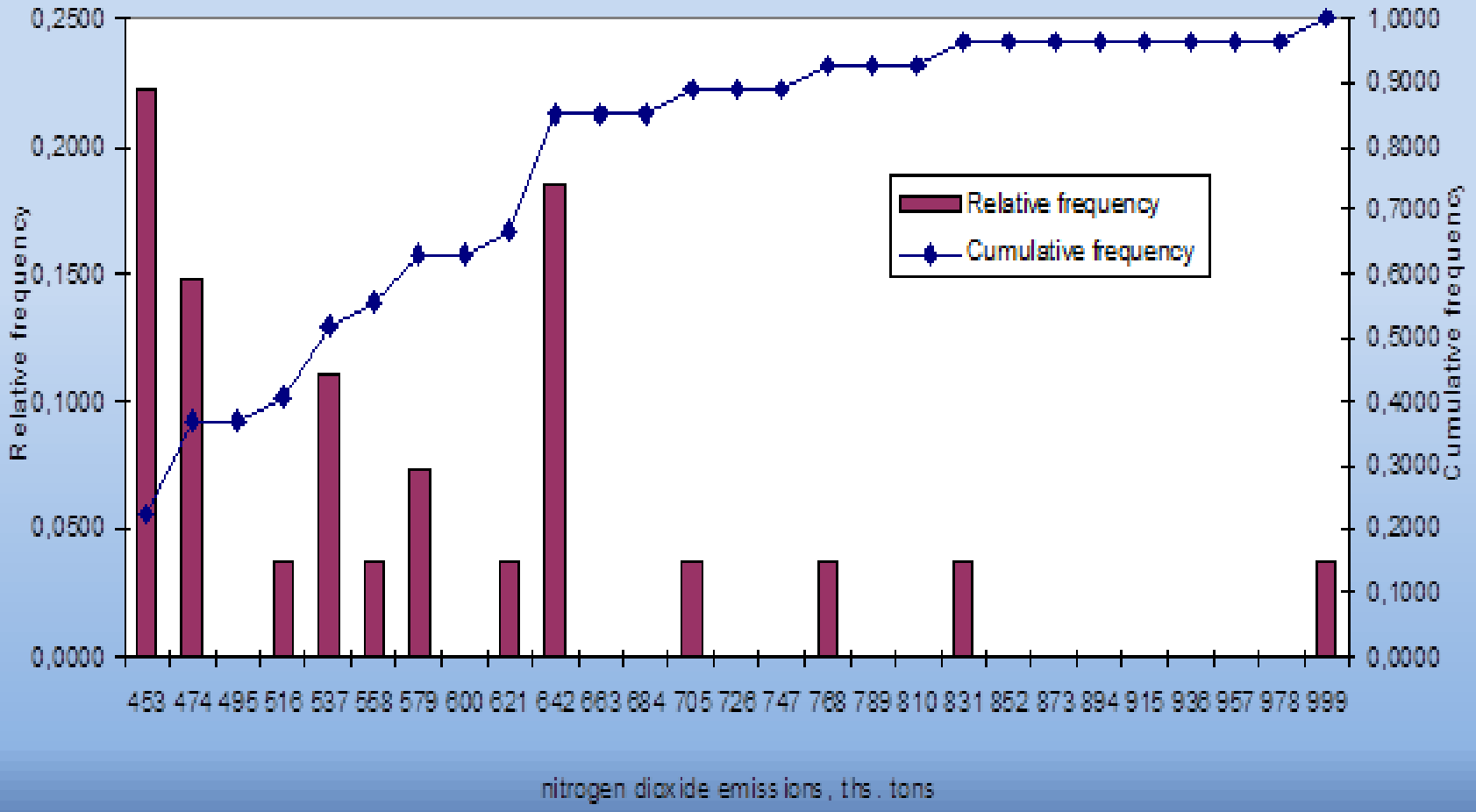


Figure 4. *Relative and cumulative frequencies of carbon monoxide emissions during 1996-2016*

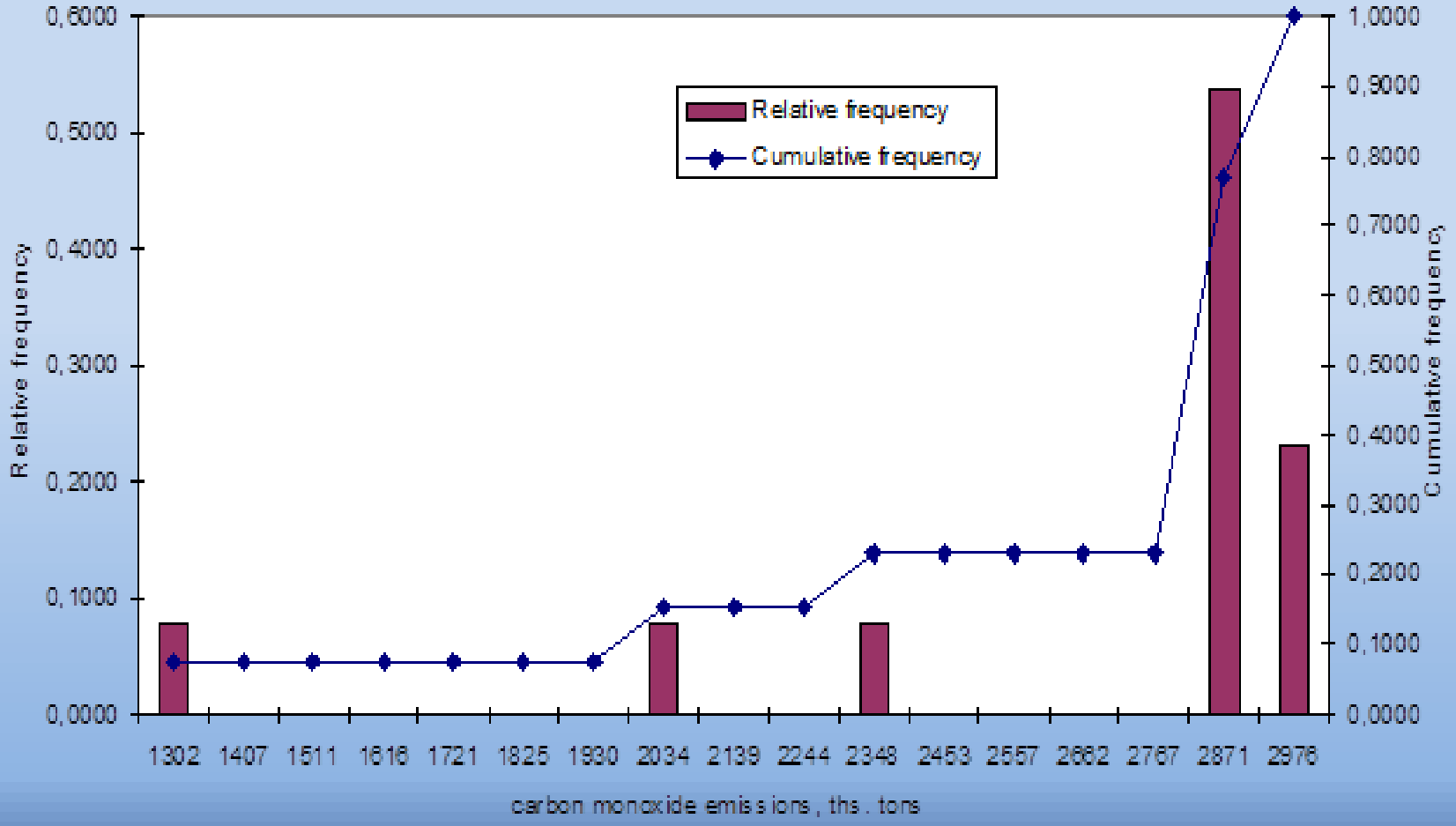
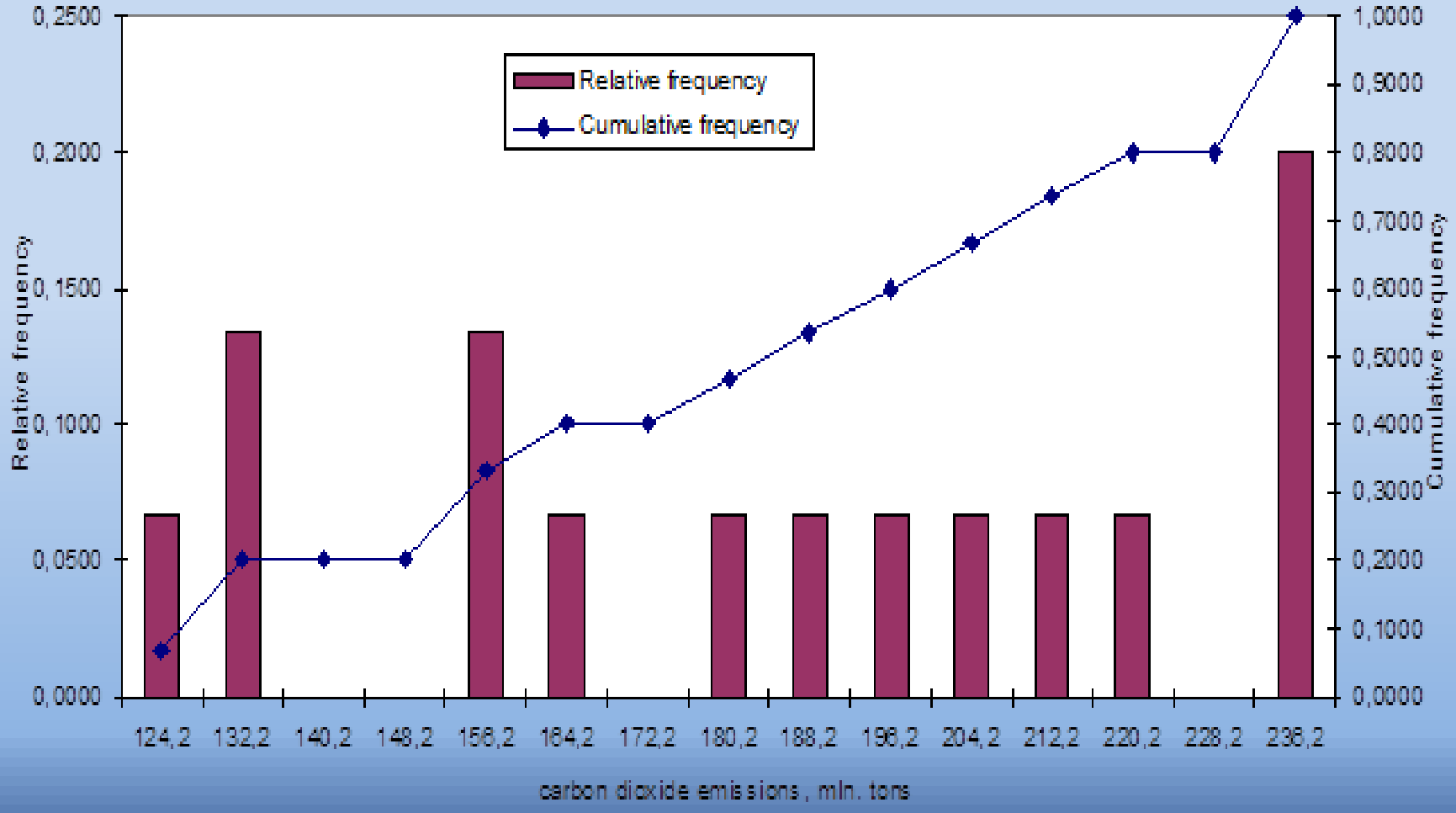


Figure 5. *Relative and cumulative frequencies of carbon dioxide emissions during 2000-2018*



The optimal values of growth rates of pollutant emissions have been

It has been found out that for **sulfur dioxide** they are 96.0%. This means that emissions` growth rate`s slowdown at 4% per year will strengthen ecosystem`s sustainability. When applying the second method, we obtain the following results: 0.95 confidence level provide the limits of allowable changes of sulfur dioxide emissions growth rates of 97,28 $\pm$ 5,0356%.

Optimal values for growth rates of **nitrogen dioxide** emissions : 85.6 and 101.6%. That is, these values that do not pose a threat to the ecosystem`s sustainability. Slowing down the emissions` growth rate at 14.4% per year will strengthen the ecosystem`s sustainability. When applying the second method, we obtain the following results: 0.95 confidence level provide the limits of allowable changes of nitrogen dioxide emissions` growth rate at 99.28$\pm$ 4.9249%.

The growth rate of **carbon monoxide** emissions was an average 101.24%. This indicates that, unfortunately, there was no steady emission growth slowdown during 1991-2017, i.e. there was a lack of conditions for strengthening the ecosystem`s sustainability.

Conclusions

- Economic and statistical modelling of totals and rates of growth of pollutant emissions during 1991 - 2017 has been made applying statistical indicators of relative and cumulative frequency for the following substances: sulfur dioxide, nitrogen dioxide, carbon monoxide and carbon dioxide.
- It has been proposed to consider the reliability degree equal to half of the confidence interval for the general arithmetic mean of pollutant emissions growth rate as the limits of Ukrainian environmental system`s sustainable development. The obtained results have been verified by the estimation using the confidence interval for the mean values.
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- It has been found out that the optimal\limit emission values of sulfur dioxide(1077,5 and 1375,5 thousand tons\1397,6 $\pm$ 200,0689), nitrogen dioxide(453 and 642 thousand tons\568,6852 $\pm$ 53,2569) and carbon dioxide (2871,2 and 2975,8 thousand tons\2763,62 $\pm$ 257,0544).
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- The optimal growth rates of sulfur dioxide emissions are 96,0%. The limits of the allowable change in sulfur dioxide emissions growth rate will be 97,28 $\pm$ 5,0356%. Optimal values of nitrogen dioxide emissions growth rates are 85,6 and 101,6%. That is, these values do not pose a threat to the ecosystem`s sustainability. Emissions` growth rate slow down at 14.4% per year will help to strengthen ecosystem`s sustainability. The limits of the allowable change in nitrogen dioxide emissions growth rate will be 99,28 $\pm$ 4,9249%. It has been revealed that carbon monoxide emissions` growth rate was an average 101.24%, i.e. during 1991-2017 the emission growth was in steady slowdown, that is there were no prerequisites for ecosystem`s sustainability strengthening. It will be possible to strengthen the ecosystem`s sustainability, if the emissions` growth rate slows down by 5% or more. The following growth rates of carbon dioxide emissions can be considered as allowable: 85,97 and 120,97%. That is, these values do not threaten the ecosystem`s sustainability.

Thanks for your attention!