

*V. T. Shvets*

Odesa National Academy of Food Technologies  
ONAFТ, str. Kanatna, 112, Odesa, Ukraine, 65039  
E-mail: [valtarmax@ukr.net](mailto:valtarmax@ukr.net)

## ENTROPY AND ELECTIONS. SOCIAL SYSTEMS ANALYSIS BY STATISTICAL PHYSICS METHODS

The article proposed a formula for assessing the level of freedom of choice of a person during elections, similar to the formula is used to compare the freedom of elections in the presidential and parliamentary elections in Ukraine.

### Introduction

Statistical physics confidently gains new positions in the areas, which seemingly have nothing to do with it. One of the fundamental concepts of statistical physics is the concept of entropy. In 1877, the brilliant Austrian physicist Ludwig Edward Boltzman was the first to understand the connection between the entropy of the physical system and the probability of its stay in one or another macroscopic state associated with the number of microscopic states that implement this macroscopic state [1-4]. In 1948, the famous American electrical engineer and mathematician Claude Elwood Shannon proposed to use the concept of entropy to assess the uncertainty of information about a particular event [5-7]. Thus, he launched a new mathematical discipline - the theory of information, where entropy was called information entropy. The connection of information entropy with the probability of the onset of a particular event, he proposed in the same form as the connection of the system's stay in one or another macroscopic state, that is, actually used the Boltzman formula for information entropy. Consider the formula for information entropy.

### Entropy, information entropy and election entropy

Let us conduct a random experiment with the consequences  $E_1, E_2, \dots, E_n$ , that can be implemented with probabilities of  $p_1, p_2, \dots,$

$p_n$ . Then the information we received in the afterbirth of this experiment is a random value that takes the value  $I(E_i)$  when the experiment is a consequence  $E_i$ . At the same time

$$I(E_i) = -\log_2(p_i).$$

The mathematical expectation of this information (information entropy), that is, the average amount of information that accounts for one consequence of the experiment, is determined in a standard way [8]

$$M(I) = \sum_{i=1}^n p_i I(E_i).$$

The last result can be recorded in a form adopted for statistical physics and information theory

$$S = -\sum_{i=1}^m p_i \log_2(p_i).$$

Many political processes resemble a random experiment. In particular, in our opinion, this process is elections of different levels. If the possible consequences of this political process are considered to be the victory of a particular candidate, i.e. the events of  $E_1, E_2, \dots, E_n$  with probabilities  $p_1, p_2, \dots, p_n$ , you can use the previous formula to assess the election results. Now it would be expedient to use instead the term information entropy of the term election entropy. First of all, it characterizes the level of uncertainty of the election results. The more candidates for an elected posi-

tion and the more evenly the probabilities of victory of different candidates are distributed, the greater is the entropy of elections, the greater is the information entropy. This universal property of entropy was also warned by Ludwig Edward Boltzman.

In the case of two candidate who have equal chances to win, that is, in the simplest political random experiment of election entropy, as well as information entropy, we get the result 1. In theory of information, this amount of information is called a bit. In our case, it would be more appropriate to call it differently, for example, fried - from the first letters of the English word freedom. It is precisely in order for in the simplest political experiment that we get the answer unit, the logarithm in the formula for the entropy of elections is advisable to take on the basis of two.

It should be noted that in many countries, the level of democracy in which is considered high, in fact, elections take place between two candidates with approximately equal chances of winning. It is clear that in this case, the entropy of choice will be quite small, compared to, for example, with Ukraine.

In the Soviet Union, elections have always been held on a non-alternative basis. This means that one of the probabilities, for example, is  $p_1=1$ , and all others are zero. In this case, the formula for election entropy gives zero result.

Is the elections are held in two rounds, then for the second round you should use the same formula for election entropy, and the results, according to the universal properties of entropy of two independent subsystems of the same system, should be compiled

$$S = S_1 + S_2,$$

where

$$S_1 = - \sum_{i=1}^m p_i \log_2(p_i),$$

$$S_2 = - \sum_{i=1}^2 P_i \log_2(P_i).$$

From our point of view, the uncertainty of the election results indicates the level of voter freedom in such elections, that is, the level of freedom of the elections themselves. Therefore, since there are no competing options for definition for obvious reasons, we propose to

call the entropy of elections a level of freedom of elections. At the same time, if a voter votes for  $i$ -th candidate, he exercises his freedom of choice in quantitative terms as  $-\log_2(p_i)$ .

The question of the source of information about the probabilities of victory of individual candidates is important. In fact, the main source of information about these probabilities is the election results. Then these probabilities are simply equal to the fates of voters who voted for this candidate. Quite accurately, information can be obtained about these probabilities and based on the study of various sociological studies, but this is also an election with a rather limited sample size, that is, voters.

Such a political substance as power is inextricably linked with elections. Unrestricted power never relies on any elections. In 1917, the Bolsheviks came to power in the Russian Empire without receiving a mandate for power from voters. Their power was frightening. Then the Communist Party began to imitate elections in some secondary levels of public administration, conducting them on a non-alternative basis. The entire party hierarchy, which had absolute power in the country, never received the mandate of voters. It seems to us that such a concept as power is inextricably linked with such a well-defined characteristic as entropy, or rather the entropy of elections. As such a connection, we offer its simplest option. The government, the mandate for which elections are given, is the value inverted to the entropy of elections, that is,

$$V = 1/S.$$

In this case, the power gained in non-alternative elections, or without edict at all, is absolute. In our mathematical model is infinite. Such was the power of the Communist Party in the Soviet Union, as is the current power of the Communist Party in China.

### **Presidential and parliamentary elections in Ukraine**

It is quite useful to test the proposed formulas based on the results of the elections in Ukraine. On the Internet, the relevant information is easily accessible, so in the future we will not use specific links to its sources. The following chart shows the results of the presi-

dential elections in Ukraine during the years of independence.

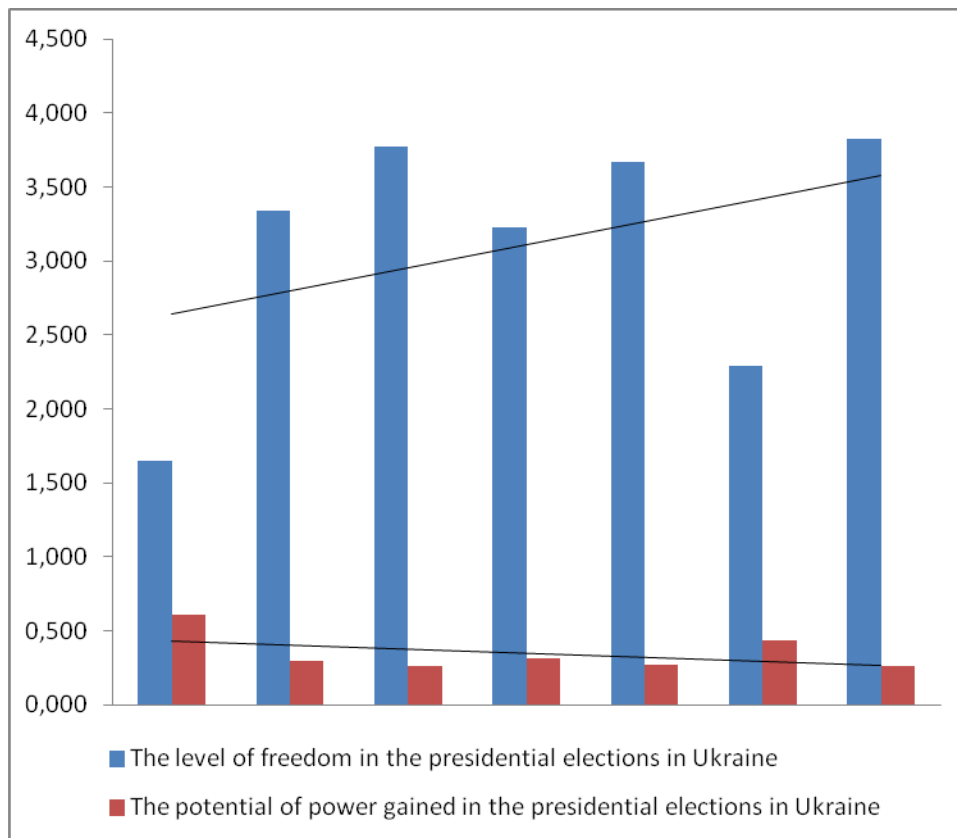


Fig 1.

The diagram shows that the level of freedom of elections in Ukraine is extremely high, possibly the highest in Europe. This level was the lowest at the first elections in the modern history of Ukraine. In our opinion, this was due to the inertia of thinking of voters, as well as candidates, as a result of the recent Soviet past. This level was relatively small in elections in 2014. Then Ukraine was imminent war with the Russian Federation. The wishing to lead the state at this tragic time for Ukraine was relatively small. Elections in two rounds would be too dangerous for the country. The responsibility of voters for the fate of the state determined just such a result. One of the candidates confidently won in the first round.

The highest level of freedom of elections was at the last elections in 2019. Here the elections were held in two rounds. The number of candidates was unprecedentedly high. The winner of the second round in the first received only a little more than thirty percent of the votes.

If we follow all the presidential elections in independent Ukraine, then there is a clear tendency to increase the level of freedom of elections.

The second significant result of the presidential election is that the potential of the government gained by the winner of the elections is quite small, perhaps the smallest in Europe, and this potential tends to decrease. That is, the freer the elections, the less power delegated by voters ends up in the hands of the winner. The level of freedom of elections is the level of real power of the people. The potential of power is, in fact, the real power of the winner. If the winner forgets about the limits of his power, then the rebellion of the people with tragic consequences for the usurper is inevitable. Such experience is already in recent Ukrainian history. The following charts show similar results of parliamentary elections in Ukraine during the years of independence

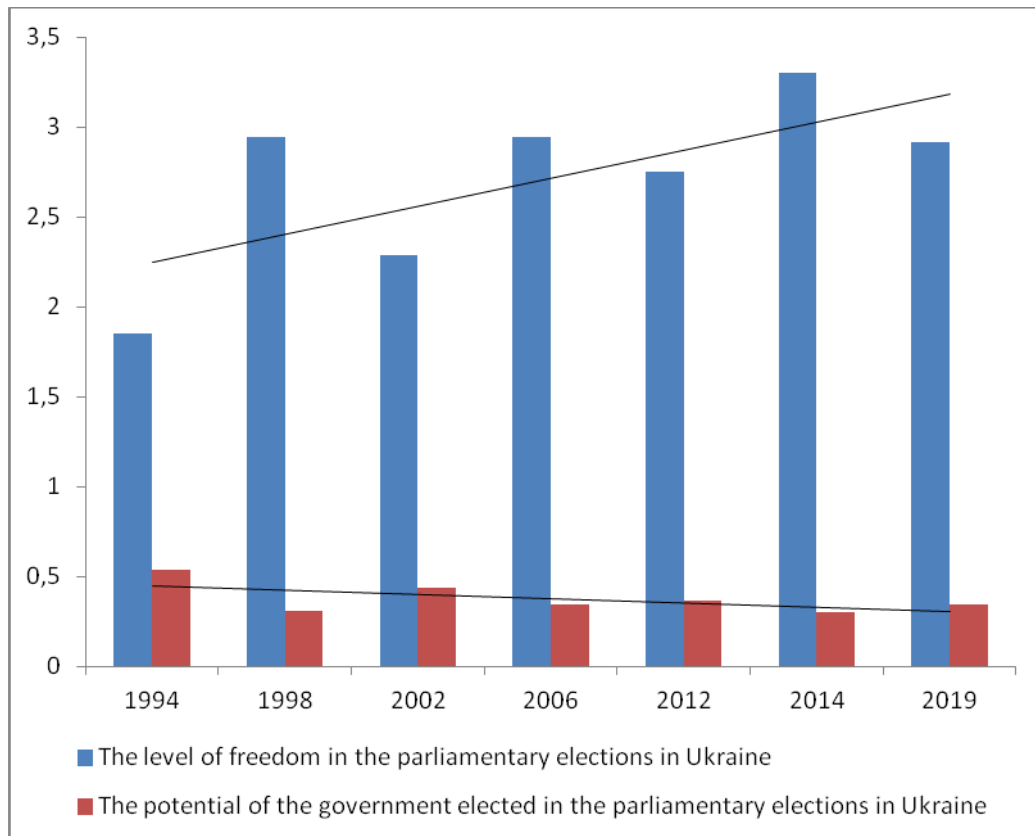


Fig. 2.

The level of freedom in parliamentary elections is also quite high and correlates well with the level of freedom of presidential elections. It also tends to grow. The lowest freedom of elections was in the first parliamentary elections in 1994, which is consistent with the lowest rate of presidential elections. However, it was the highest for Ukraine in 2014. The real chances of winning were given to more political parties, and the votes were more evenly distributed between them than in other parliamentary elections. Having elected in May the president, a Ukrainian voter on a patriotic wave brought a huge number of nationally conscious deputies to parliament. There were also parties that, under other conditions, did not have such a chance. The parliament did not have a large number of deputies from the regions of Ukraine occupied by the Russian Federation, traditionally orthogonal to Ukrainian values. Parliament has never

worked as effectively as it did between 2014 and 2019.

### **Presidential and parliamentary elections in the Russian federation**

Ukrainian elections are most useful compared with elections in countries that arose on the ruins of the Ukrainian elections are most useful compared with elections in countries that arose on the ruins of the Soviet Union. An important factor here is the commonality of the starting political and economic conditions. Also an important aligning factor is the mentality of the Soviet person, present in all, even the most remote corners of the former Soviet Union at the time of its collapse. If the election results in different countries revealed significant differences, then these differences, first of all, would be due to differences in ethnic origin.

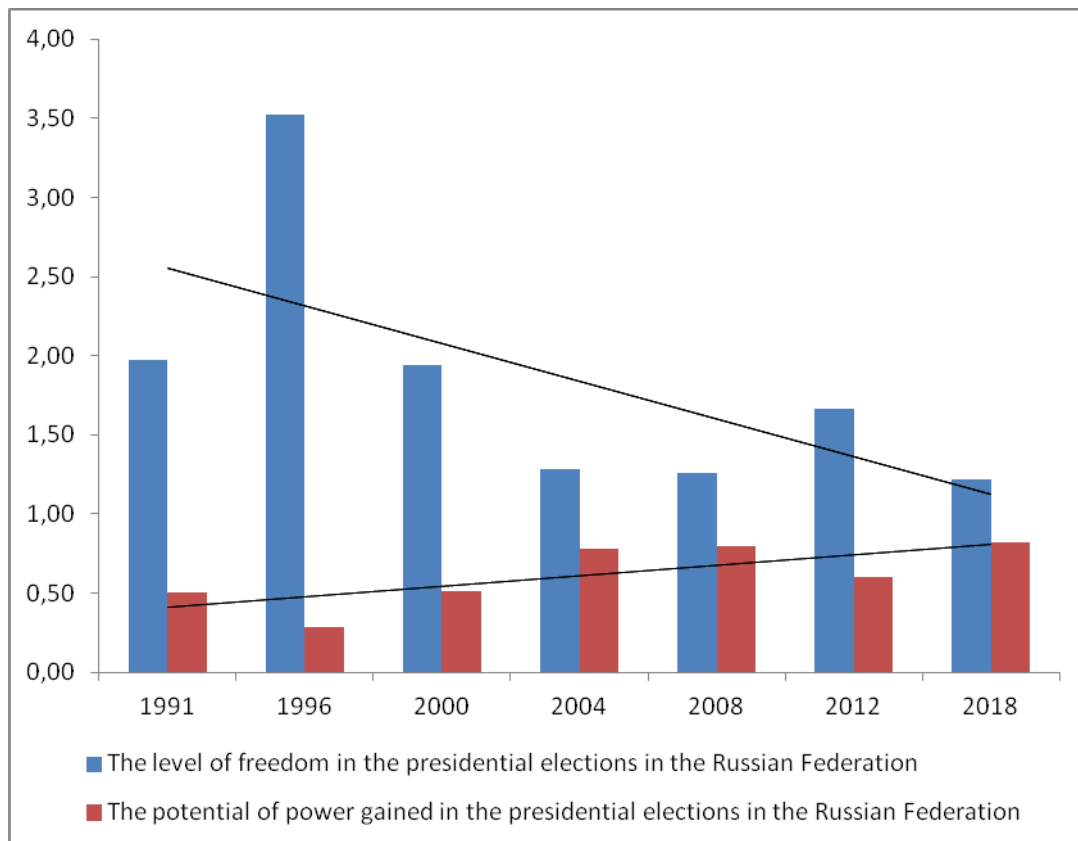


Fig. 3.

The choice of the Russian Federation as an object for comparison is quite understandable for various reasons. Of course, it would be extremely expedient to conduct a comparative analysis of all the countries formed on the territory of the former Soviet Union, but this is already material for many subsequent publications. The results of the elections in the Russian Federation are also easily accessible from the Internet and we will not make special links to these results.

The diagram shows that the level of freedom of the presidential elections in the Russian Federation immediately started from a fairly high level in 1991. In 1996, it peaked, and in the last almost twenty years it has shown an obvious tendency to decrease. The direct reasons for this behavior of the level of freedom of elections are both a decrease in the number of candidates and an increase in the uneven distribution of votes between them. That is, a large number of candidates receives a symbolically small number of votes, but one of the candidates receives an unprecedentedly

high number of them.

An interesting trend is the tendency to significantly increase the potential of the president's power in the Russian Federation over the past twenty-eight years. Starting from a level typical of other democracies, it quickly increased to a level that can be called authoritarian.

The results of the parliamentary elections are given in the following chart. This chart also demonstrates the high level of freedom of parliamentary elections in the Russian Federation in 1994, 1996, 2000. However, it also demonstrates a powerful tendency to reduce this level over all the years analyzed. There is also a strong correlation between the results of the presidential and parliamentary elections. Such a correlation, as in the case of Ukraine, indicates, in our opinion, the objective nature of the election process for each people, no matter what the elections are called. That is, the nature of elections is an imprint of the mentality of one or another people, its fundamental ethnic values.

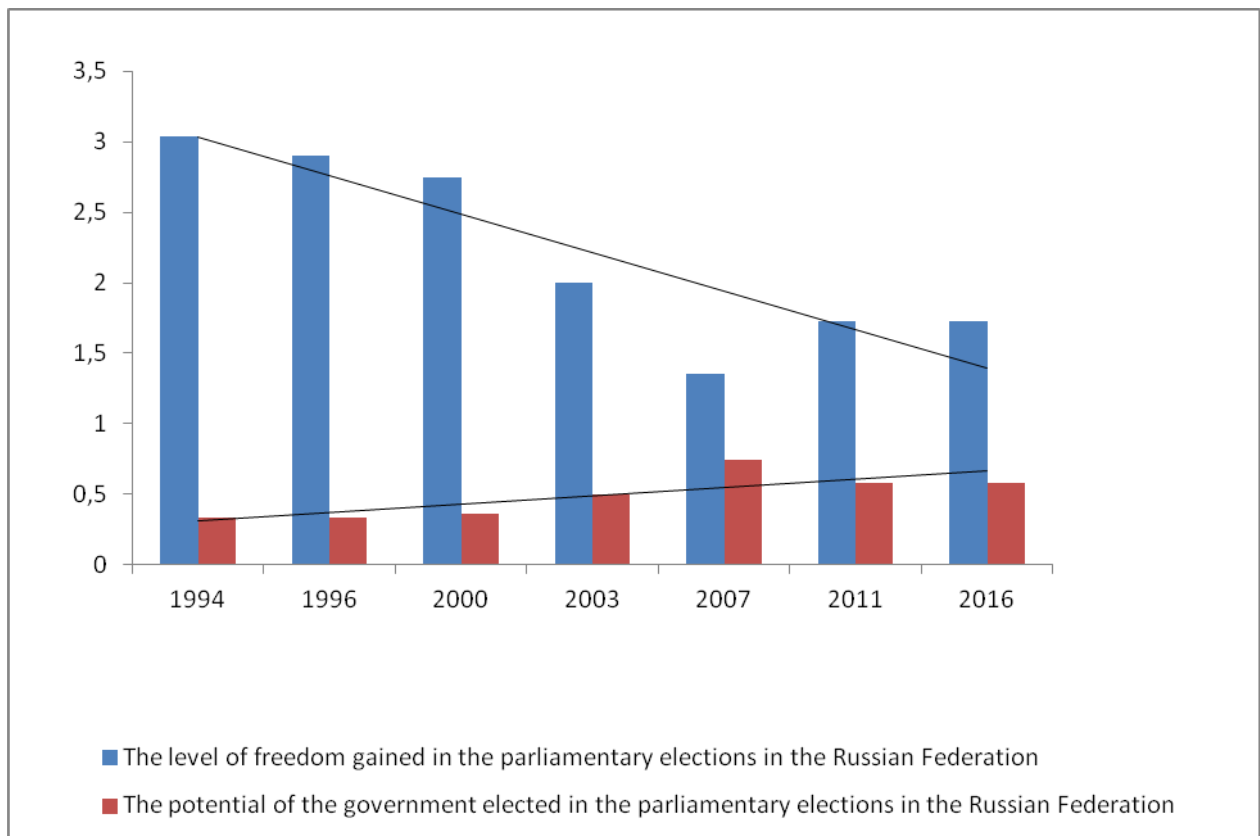


Fig. 4.

### Comparison of elections in Ukraine and in the Russian federation

Only comparing the results of elections in different countries makes it possible to decide on our own place in the modern world political process. In the following chart, this comparison is given for the presidential elections in Ukraine and the Russian Federation.

The chart shows that the level of freedom of elections in 1991 started in both countries from almost the same level. This can be explained by the inertia of thinking of Ukrainians and residents of the Russian Federation. Generations of voters in both countries were fully formed in the conditions of the same political reality – the Soviet Union. But over time, disagreements began to increase. This happened as generations of politically formed or even born in an independent Ukrainian state began to come to the electoral urns in Ukraine. Accordingly, the number of voters whose outlook was formed in the Soviet Union began to decrease significantly for natural reasons. The same evolution began among voters of the Russian Federation, but in the exact opposite

direction. It seems that Soviet education was a compromise for the various ethnic groups that inhabited the Soviet Union. The collapse of the Soviet Union was both the disappearance of this compromise.

Then began the evolution of each ethnic group to its own, characterized by its mental worldview. In the result, we received the highest level of freedom of choice in the last presidential elections in Ukraine, and the lowest in the presidential elections in the Russian Federation, respectively. At the same time, these results differ significantly.

In the following chart, we have a comparative analysis of the presidential elections in both countries.

Freedom of parliamentary elections in Ukraine and the Russian Federation will also differ significantly in favor of greater freedom of elections in Ukraine compared to the Russian Federation. For Ukraine, there is a clear tendency to increase freedom of elections, for the Russian Federation there is a clear tendency to reduce it. However, there are certain differences.

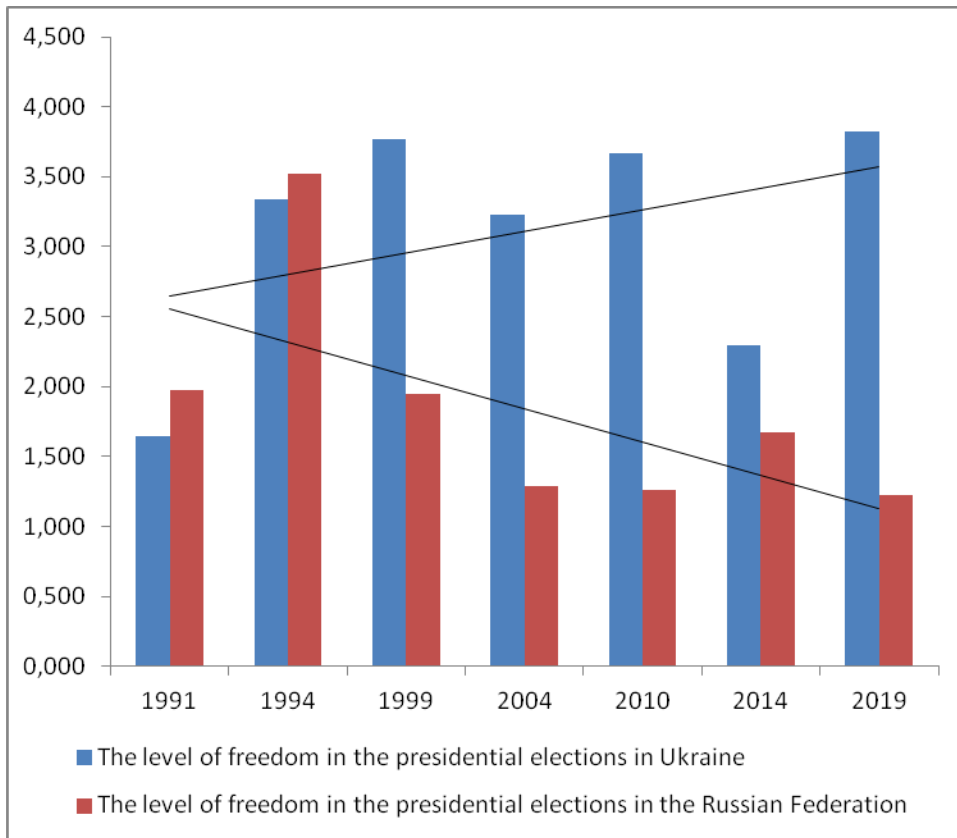


Fig 5.

Freedom of parliamentary elections in the Russian Federation started from higher values compared to Ukraine.

The tendency to significantly reduce the freedom of parliamentary elections in the Russian Federation has become clear over the past twenty years, when the concentration of power in the hands of the president has increased markedly.

As in the case of presidential elections, the results of all recent parliamentary elections in both countries differ significantly in favor of significantly greater freedom of elections in Ukraine.

From the above comparative analysis of the presidential and parliamentary elections in Ukraine and the Russian Federation, we be-

lieve that the significant difference in the results of elections in both countries for almost thirty years indicates a significant mental difference between Ukrainians and residents of the Russian Federation. Most likely, this distinction is programmed at the genetic level.

The very opportunity to notice and analyze the smallest details of both presidential and parliamentary elections in both countries at the number level indicates, in our opinion, that the formulas proposed by the author for quantitative analysis of elections are an effective tool for quantitative research of this political process. We are confident that this approach can be applied to quantitative analysis and other aspects of the political life of our country.

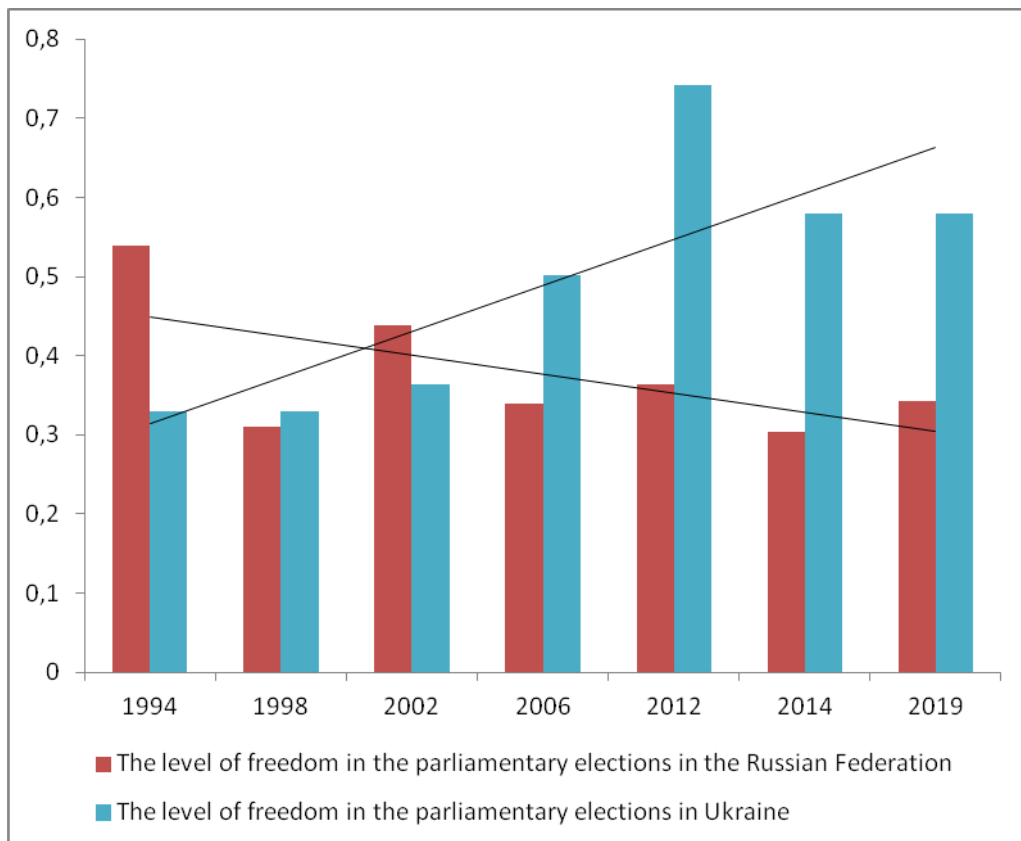


Fig. 6.

The author expresses sincere gratitude to his colleagues for the fruitful discussion of the results of the article [9], as well as Yuriy Ivanovich Radkovets not only for useful discussions, but also for the very idea of applying the mathematical apparatus to the analysis of political processes.

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Shvets V. T.



## **ENTROPY AND ELECTIONS. SOCIAL SYSTEMS ANALYSIS BY STATISTICAL PHYSICS METHODS**

### **Summary**

The paper proposes a formula for assessing the level of human freedom of choice during elections, similar to the formula for entropy in statistical physics and informational entropy in information theory. The formula is used to compare the freedom of elections in the presidential and parliamentary elections in Ukraine and the Russian Federation. **Keywords:** entropy, probability, freedom of choice, presidential elections in Ukraine, parliamentary elections in Ukraine.

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Швець В. Т.

## **ЕНТРОПИЯ І ВИБОРИ АНАЛІЗ СОЦІАЛЬНИХ СИСТЕМ МЕТОДАМИ СТАТИСТИЧНОЇ ФІЗИКИ**

### **Резюме**

У статті запропонована формула оцінки рівня свободи людини під час виборів, аналогічна формулі для ентропії у статистичній фізиці і інформаційній ентропії у теорії інформації. Формула застосована для порівняння рівня свободи на президентських і парламентських виборах в Україні і Російській федерації.

**Ключові слова:** ентропія, свобода вибору, президентські вибори в Україні, парламентські вибори в Україні.

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Швець В. Т.

## **ЕНТРОПИЯ И ВЫБОРЫ. АНАЛИЗ СОЦИАЛЬНЫХ СИСТЕМ МЕТОДАМИ СТАТИСТИЧЕСКОЙ ФИЗИКИ**

### **Резюме**

В статье предложена формула оценки уровня свободы человека во время выборов, аналогичная формуле для энтропии в статистической физике и информационной энтропии в теории информации. Формула использована для сравнения уровня свободы на президентских и парламентских выборах в Украине

**Ключевые слова:** энтропия, вероятность, свобода выбора, президентские выборы в Украине, парламентские выборы в Украине.

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