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5.2.2. Математические, статистические и инструментальные методы в экономике (физико-математические науки, экономические науки)

СОСТОЯНИЕ И ПЕРСПЕКТИВЫ РАЗВИТИЯ СТАТИСТИЧЕСКИХ МЕТОДОВ В ЭКОНОМИКЕ

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В научной специальности 5.2.2 «Математические, статистические и инструментальные методы в экономике» одна из трёх основных составляющих – это «статистические методы в экономике». В статье кратко рассмотрены история и современное состояние статистики как самостоятельной науки, а также обсуждены перспективы её развития. Статистические исследования проводятся с древнейших времён. В Ветхом Завете есть Четвертая книга Моисеева, которая называется «Числа». В ней рассказывается о переписи военнообязанных – в 12 коленах переписаны 603550 человек. Сотрудниками Межфакультетской лаборатории статистических методов МГУ им. М.В. Ломоносова собрано около 200 определений термина «статистика», взятых из публикаций как отечественных, так и зарубежных авторов. Эти определения позволяют проследить изменение содержания термина «статистика» во времени. Более 150 лет назад выделены две ветви статистической науки, на которые она делится и в настоящее время. Первая – развитие статистических методов. Вторая – ведомственная наука Росстата. Рассмотрена смена парадигм в развитии статистических методов. Современная революция в математических и статистических методах исследования основана на новой парадигме статистики. Одна из её черт - переход от прежних математических чисел к прагматическим числам, характерной чертой которых является нечёткость (размытость, расплывчатость), и создание системной нечёткой интервальной математики. Поскольку распределения реальных данных, как правило, нет оснований считать нормальными (гауссовскими), необходимо развивать и использовать непараметрические методы статистики. В ходе научной революции

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5.2.2. Mathematical, statistical and instrumental methods of economics (physical and mathematical sciences, economic sciences)

THE STATE AND PROSPECTS OF DEVELOPMENT OF STATISTICAL METHODS IN ECONOMICS

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In the scientific specialty 5.2.2 "Mathematical, statistical and instrumental methods in economics", one of the three main components is "statistical methods in economics". The article briefly examines the history and current state of statistics as an independent science, as well as discusses the prospects for its development. Statistical research has been conducted since ancient times. There is a Fourth Book of Moses in the Old Testament called Numbers. It tells about the census of those liable for military service – 603,550 people were registered in 12 tribes. The staff of the Interfaculty Laboratory of Statistical Methods of Lomonosov Moscow State University has collected about 200 definitions of the term "statistics" taken from publications by both domestic and foreign authors. These definitions allow us to trace the change in the content of the term "statistics" over time. More than 150 years ago, two branches of statistical science were distinguished, into which it is still divided. The first is the development of statistical methods. The second is the departmental science of Rosstat. A paradigm shift in the development of statistical methods is considered. The modern revolution in mathematical and statistical research methods is based on a new statistical paradigm. One of its features is the transition from the old mathematical numbers to pragmatic numbers, which are characterized by fuzziness (blurriness, vagueness), and the creation of systematic fuzzy interval mathematics. Since the distributions of real data, as a rule, there is no reason to consider normal (Gaussian), it is necessary to develop and use nonparametric statistical methods. During the scientific revolution, non-numerical data statistics became the central area of applied statistics. The role of computer technology, information and communication technologies, and artificial intelligence has increased dramatically. The unsatisfactory state of

центральной областью прикладной статистики стала статистика нечисловых данных. Резко возросла роль компьютерной техники, информационно-коммуникационных технологий, искусственного интеллекта. Обсуждается неудовлетворительное состояние «росстатовской» ветви статистической науки в нашей стране. Наиболее важной задачей на современном этапе является широкое распространение информации о революции в математических и статистических методах исследования и полученных в соответствии с ней научных результатов на основе современной парадигмы

the "Rosstat" branch of statistical science in our country is discussed. The most important task at the present stage is to widely disseminate information about the revolution in mathematical and statistical research methods and the scientific results obtained in accordance with it based on the modern paradigm

Ключевые слова: СТАТИСТИЧЕСКИЕ МЕТОДЫ, ОПРЕДЕЛЕНИЯ СТАТИСТИКИ, РАЗВИТИЕ, СМЕНА ПАРАДИГМ, НАУЧНАЯ РЕВОЛЮЦИЯ, СИСТЕМНАЯ НЕЧЕТКАЯ ИНТЕРВАЛЬНАЯ МАТЕМАТИКА, ОТЕЧЕСТВЕННАЯ СТАТИСТИЧЕСКАЯ НАУКА

Keywords: STATISTICAL METHODS, DEFINITIONS OF STATISTICS, DEVELOPMENT, PARADIGM SHIFT, SCIENTIFIC REVOLUTION, SYSTEM FUZZY INTERVAL MATHEMATICS, RUSSIAN STATISTICAL SCIENCE

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Introduction

In the scientific specialty 5.2.2 "Mathematical, statistical and instrumental methods in economics (physical and mathematical sciences, economic sciences)" one of the three main components is "statistical methods in economics". Previous versions of the list of scientific specialties of the Higher Attestation Commission contained two specialties:

08.00.12 – Accounting, statistics (economic sciences);

08.00.13 – Mathematical and instrumental methods of economics (economic sciences).

These two specialties were combined. What is the contribution of specialty 08.00.12 to the combined specialty? To answer this question, it is necessary to identify the main content of the statistical component of specialty 08.00.12. This content is reflected in numerous textbooks under the titles "Statistics" and "General Theory of Statistics".

For such an analysis, it is appropriate to briefly review the history and current state of statistics as an independent science, and then discuss the

prospects for the development of statistical methods in economics. This article is devoted to these issues.

Brief history of statistics

In our country, the most authoritative scientific center in the field of statistics was the Interfaculty Laboratory of Statistical Methods of the Moscow State University named after M.V. Lomonosov, created by Academician of the USSR Academy of Sciences A.N. Kolmogorov. The work published by the staff of this laboratory [1] provides about 200 definitions of the term "statistics", taken from publications of both domestic and foreign authors. These definitions allow us to trace the change in the content of the term "statistics" over time.

Statistical research has been conducted since ancient times. Thus, in the Bible in the Old TestamentThere is the Fourth Book of Moses, which is called "Numbers". It tells about the census of those liable for military service. Its results are given - 603,550 people were registered in 12 tribes. In the future, statistical studies were constantly conducted, primarily for taxation purposes. In our country, they were called "audit tales".

The business idea of the entrepreneur Chichikov, the hero of N.V. Gogol's "Dead Souls", is based on the peculiarities of statistical recording of the population. Peasants who died after the last census were considered alive from the state's point of view. They could be sold. This was profitable for the landowners, since taxes had to be paid for the peasants. Chichikov planned to buy a sufficient number of "dead souls" at a low price, pawn them in a bank and get a loan. Then he planned their "removal" (resettlement) to the outskirts of the Russian Empire - to the Astrakhan province. The final step - the local authorities recognize them as having died of cholera (for an appropriate bribe), on the basis of which the bank releases Chichikov from the need to repay the loan he took.

The Bible does not contain the words "statistician" or "statistics". As prof. V.V. Nalimov writes in the preface to the work [1, p.3], the word "statistician"

first appears in fiction - in "Hamlet" (1602). In this play, courtiers are called statisticians. It can be assumed that the original is the Latin word status, the meaning of which is a political state.

The first definition given in[1, p. 6], dates back to 1749. It is as follows: "…the so-called statistics is the science of government (the science of governance) of an individual state… Government contains basic information about the characteristic features of a civilized society."

For more than 100 years, all definitions included in [1, pp. 6-11] understood statistics as political science. With two exceptions. According to Napoleon Bonaparte: "Statistics is the budget of things" (not dated). It can be stated that he moved from political science to management accounting, which can be used, among other things, at a separate enterprise. The definition dates back to 1833: "The purpose of statistics is to present facts in the most concise form."

Only in the last thirdThe 19th century saw a shift away from identifying statistics with political science, although only among some authors. For example, the following definition dates back to 1868: "Statistics is the knowledge of facts based on their presentation in a form in which their numerical values can be compared" [1, p. 18].

Only in 1872a definition appears in which two branches of statistical science are clearly distinguished, into which it is divided at present: "Statistics are 1) those methods that study states and events by means of mass observations; 2) the science of many phenomena in states and groups of people, of their fluctuations and laws" [1, p. 18]. At present, the first branch is mathematical statistics and applied statistics, and the second is a departmental science of Rosstat as one of the economic disciplines.

Let us give a few more definitions.

"Statistics consists in the observation of phenomena which can be counted or expressed by means of numbers" (1895, [1, p. 22]).

“Statistics is the numerical representation of facts from any field of study in their interrelationship” (1909,[1, p. 22]).

“Statistics is the set of methods and principles by which numerical data are collected, analyzed, compared, presented, and interpreted” (1925,[1, p. 25]).

In 1954, Academician of the Academy of Sciences of the Ukrainian SSR B.V. Gnedenko gave the followingan expanded definition that seems to us the most adequate:

“The statistics consist of three sections:

1) collection of statistical information, i.e. information characterizing individual units of any mass population;

2) statistical study of the obtained data, which consists of identifying those patterns that can be established on the basis of mass observation data;

3) development of methods of statistical observation and analysis of statistical data. The last section, in fact, constitutes the content of mathematical statistics” [1, p. 31].

In the same year, R.A. Fisher wrote: “Statistics as a science is one of the sectionsapplied mathematics, and it can be considered as mathematics applied in the development of the results of mass observation” [1, p. 31].

And morethree definitions.

According to B.L. Vander Waerden: “…the key question of mathematical statistics is the question: how far can the values calculated from a sample deviate from the corresponding ideal values?” (1960, [1, p. 33]).

«The methods by which statistical data are collected, summarized, and used in a generalized manner are known as statistical methods or statistics” (1968, [1, p. 42]).

“I like the following short and to the point definition of statistics:"Statistics is the study of the collection and interpretation of data" (1968, [1, p. 43]).

In the definitions given, leading experts note various aspects of statistical science. Part 1 of the monograph [2, pp. 7-86] is devoted to its development. Statistical methods in economics have a second name – econometrics [3].

Scientific revolutions

To consider the status and prospectsIn order to develop statistical methods in economics, we will need the concept of “scientific revolution”.

According to one of the leaders of the historical-evolutionary trend in the philosophy of science, T. Kuhn: “Scientific revolutions are non-cumulative episodes in the development of science, during which the old paradigm is replaced in whole or in part by a new paradigm that is incompatible with the old” [4, p. 129]. The concept of “scientific revolution” is widely discussed by specialists in various fields, primarily philosophers (see, for example, [5]). Revolutions in physics are well known (during the transition from Aristotle to Newton and in the 20th century, associated with the creation of quantum mechanics, nuclear physics and the theory of relativity).The revolution in biology was caused by the emergence of genetics, the revolution in history by the creation of a new statistical chronology.

In this series there is also a revolution in mathematical and statistical research methods [6], based on a new paradigm in this scientific and practical field.In earlier publications we used the term "new paradigm" but not the term "scientific revolution". As T. Kuhn writes (see above), the concepts corresponding to these terms are inextricably linked. Using the example of applied mathematical statistics, we compared 17 main characteristics of the old and new systems of ideas, views and concepts (i.e. the old and new paradigms) in our article [7] in 2013.

It is necessary to discuss various aspects of the revolution in mathematical research methods, which are the subject of numerous articles in the Scientific

Journal of KubSAU. In order not to clutter the article, we will indicate only the year, number and pages in square brackets.

We have repeatedly addressed the discussion of the new paradigm of mathematical and statistical research methods, in particular, in [2014. No. 98. Pp. 105–125] and [2016. No. 122. Pp. 807–832]. It was preceded by two paradigms, which we designated in [6] as primitive and outdated.

The first of them corresponds to the descriptive stage of development of statistical science [2], at which certain individual heuristic methods of data analysis were used. For example, construction of tables, calculation of sample arithmetic mean, the method of least squares. The first scientific revolution in mathematical research methods is the emergence of the classical theory of mathematical statistics, which by the middle of the 20th century was basically developed. The corresponding paradigm is reflected, in particular, in textbooks on probability theory and mathematical statistics, which are used by students of various specialties to study today.

We consider this paradigm obsolete. It has been replaced by a new (modern) paradigm, the foundations of which were identified in the scientific and public movement of the 1980s, which led, in particular, to the creation of the All-Union Statistical Association. This movement was slowed down in the 1990s due to the problems generated by the collapse of the Soviet Union. A revival occurred already in the 21st century. A large number of monographs, textbooks, and scientific articles prepared in accordance with the new paradigm of mathematical research methods have appeared.

It should be noted that in the development of mathematics, a number of scientific revolutions are distinguished. The first was the transition from empirical formulas to the emergence of mathematics as a science. In Ancient Greece, theorems, proofs, axioms appeared, primarily in geometry.

The second revolution was the creation of differential and integral calculus, the introduction of motion into the mathematics.

The third is the transition to the language of set theory, increased attention to axiomatic theories (according to Hilbert and Gödel), the transition to considering mathematics as a science of formal systems, in particular, the separation of mathematics from natural science.

The fourth revolution is happening now.

Discussions about scientific revolutions continue (see, for example, article [8]).

New paradigm of mathematicsand statistical research methods is disclosed in systemic fuzzy interval mathematics [9, 10]. We consider this new scientific field as the basis of the mathematics of the 21st century [2021. No. 165. Pp. 111–130]. It serves as the basis for the development of a modern toolkit of mathematical and statistical research methods.

IN [6] Attention was focused on two revolutionary moments. The first is the transition from the previous mathematical numbers to pragmatic numbers, a characteristic feature of which is fuzziness (blurriness, vagueness) [2013. No. 91. Pp. 255–308]. In applied statistics, this is primarily about the transition to interval data statistics [2013. No. 94. Pp. 867–892]. The second moment is related to the fact that the distributions of real data, as a rule, cannot be considered normal (Gaussian) [2016. No. 117. Pp. 71–90]. As a consequence, it is necessary to develop and use nonparametric statistical methods [2015. No. 106. Pp. 239–269].

There are still a number of points to consider.

Non-numeric data statistics

During the scientific revolution, the central area of applied statistics became the statistics of non-numerical data [2020. No. 156. Pp. 111–142]. This term has synonyms: statistics of non-numerical objects, non-numerical statistics. In this area, sample elements lie in non-linear spaces; they cannot be added or multiplied by a number. In the toolkit of classical sections of mathematical

research methods – in the statistics of numbers, vectors (in multivariate statistical analysis), functions (in the statistics of random processes and time series) – the central place was occupied by sums and functions of sums of random elements lying in linear spaces. There are no such sums in the statistics of non-numerical data; the toolkit is based on the use of distances and optimization problems.

In the 21st century, the bulk of publications on applied statistics in the section “Mathematical Research Methods” of the journal “Factory Laboratory. Diagnostics of Materials”, the main place of publication of domestic research in the field of the theory of statistical methods, are devoted to the statistics of non-numerical data [11].

This area includes, in particular, modern measurement theory. Statistical methods of data analysis are adequate only when the conclusions obtained with their help are invariant with respect to admissible transformations of the scales in which the analyzed data are measured. The main scales are scales of names, ordinal scales, intervals, ratios, differences, and ratios. They allow us to identify areas of corresponding methods of statistical data analysis [2017. No. 134. Pp. 877–907].

Statistical Methods in Economics and Computers

During the revolution in mathematical research methods, the role of computer technology, information and communication technologies, and artificial intelligence has increased dramatically [2014. No. 103. Pp. 163–195]. If, within the framework of the outdated paradigm, they were used mainly only for calculating the values of indicators and tables of distribution functions of statistical criteria, then at present they have become one of the main tools of the researcher [2019. No. 154. Pp. 55–83].

A powerful tool for developers of methods in the field of applied statistics are the limit theorems of probability theory - the law of large numbers, the

central limit theorem, etc. Mathematically oriented specialists urge to limit themselves to them. However, limit theorems are not enough for the practical use of statistical methods. It is necessary to find a limit - to find out, starting from what sample size it is possible to use the results obtained with the help of limit theorems. And to find out how to make decisions if the volume of available data is less than this limit.

Theoretical estimates of the rate of convergence usually significantly exaggerate such limits. In accordance with the new paradigm, a universal "master key" is available to the researcher - the method of statistical tests (the Monte Carlo method), in other words, simulation modeling. It is based on the use of a sequence of pseudo-random numbers, the properties of which resemble the properties of random variables considered in probability theory. The main idea is to consistently perform the following stages: development of a probabilistic-statistical model of a real phenomenon or process; planning a statistical test in which random variables are replaced by pseudo-random ones obtained using one or another sensor; conducting a large number of tests (thousands or millions); analysis of the obtained calculation results.

Limit theorems are only a necessary first step. A "small sample" is a sample for which conclusions based on limit theorems cannot be applied. In each specific problem, it is necessary to divide finite sample sizes into two classes - those for which limit theorems can be applied, and those for which this cannot be done due to the risk of obtaining incorrect conclusions. In the second case, it is necessary to calculate the distributions of statistics for specific sample sizes. Calculate using software products, since the traditional use of tables is impossible in principle due to the fact that they would have an impractically large volume.

In the outdated paradigm, the researcher sets the significance level (the probability that the null hypothesis will be rejected when it is true). He then finds the corresponding critical value from the tables, compares it with the value

of the criterion statistic, and makes a decision on whether to accept or reject the null hypothesis.Since the distributions of rank statistics are discrete, it is usually impossible to maintain a given significance level [2015. No. 114. Pp. 42–54]. The modern approach involves moving from the significance level to the achieved significance level, i.e. to the lowest significance level at which the null hypothesis is rejected for a given value of the criterion statistic. In the future, software products will make it possible to find the achieved significance level for any observed samples.

Shift in paradigms in the development of statistical methods

The modern paradigm assumes a significant role of methodology in the development and application of mathematical and statistical research methods [2014. No. 104. Pp. 53–80; 2017. No. 125. Pp. 319–345]. On its basis, the basic requirements for statistical methods of data analysis have been formed, which allow for the construction of adequate probabilistic-statistical models of real phenomena and processes, and then justify the choice of data analysis methods [2022. No. 181. Pp. 316–343]. For example, the requirement to use nonparametric statistical methods instead of parametric ones (in particular, those based on the unverifiable assumption of the normality of the distributions of measurement results) is a typical methodological requirement.

A feature of the modern stage of development of mathematical research methods is the coexistence of works carried out within the framework of all the considered paradigms - primitive, outdated and modern. Thus, the publications of the Federal State Statistics Service (Rosstat) are carried out mainly according to the primitive paradigm. They contain mainly tables, diagrams and graphs, asand works of the 19th century. However, their direct analysis in a number of cases allows us to obtain conclusions that are useful for practice.

The outdated paradigm was dominant in statistical theory in the first half of the 20th century. Initially, mathematical statistics (created as a science at the

beginning of the 20th century) dealt with the problems of estimating and testing hypotheses in relation to settings in which it was assumed that the distributions of sample elements belong to a particular parametric family. By the middle of the 20th century, parametric statistics had been mostly developed. However, some important results were obtained much later, right up to the present day. These include, for example, works that substantiate the replacement of maximum likelihood estimates with one-step estimates [2015. No. 109. Pp. 208–237], as well as publications on methods for estimating the parameters of the gamma distribution [2023. No. 192. Pp. 142–157] and the beta distribution [2023. No. 187. Pp. 184–206]. Much of the applied work is based on the outdated paradigm of parametric statistics.

At the forefront of mathematical and statistical science are studies on nonparametric and non-numerical statistics, based on the modern paradigm. Not all scientific problems have been solved. For example, an analogue of the Central Limit Theorem in the case of non-numerical data of a general nature is unknown. Further development of models and methods for analyzing the coincidence of sample elements when using nonparametric rank statistics is necessary [12]. Let us pay attention to the unsolved problems included in the “Tsaghkadzor notebook” [13] (the name is explained by the fact that the initial list of unsolved problems was compiled by participants of a conference on statistical methods in the Armenian village of Tsaghkadzor).

The state of statistical science in our country

As already noted, more than 150 years ago, two branches of statistical science were identified, into which it is divided at present. The first is the development of statistical methods. The second is the departmental science of Rosstat. Information about the first of these branches is given above. Let us discuss the second.

In our country, a large number of textbooks have been published under the titles "Statistics", "General Theory of Statistics". An analysis of their content leads to the conclusion that various statistical methods are presented.Sometimes information about the work of Rosstat and individual applied areas of work (for example, agricultural statistics) is added to them. O. B. Sheinin rightly states: “Our conclusion: only mathematical statistics can serve as a theory of statistics” [14]. (The same author has published an adequate book on the history of statistics [15].)

It is striking that the authors of such textbooks include in them only methods of descriptive and parametric statistics developed a hundred years ago or earlier., i.e. they teach within the framework of an outdated paradigm. There is not a word about nonparametric statistics or statistics of non-numerical data.

It is no less surprising that the achievements of domestic statistics of the 20th century are almost completely ignored.c. For example, in the history of the Academy of Sciences there are only two of its members (Corresponding Members N.V. Smirnov and L.N. Bolshev), who were engaged exclusively in mathematical statistics. It was they who wrote the most significant statistical book of the 20th century – “Tables of Mathematical Statistics” [16]. However, their names are not found in either the textbook [17] or the Encyclopedia of Statistical Terms[1]prepared by Rosstat in 2013 in 8 volumes. In the extensive volume 8, “Outstanding Domestic and Foreign Scientists in the Field of Statistics,” which contains information about hundreds of specialists from past centuries, there was no room for outstanding domestic researchers in the field of mathematical statistics and other statistical methods – for N.V. Smirnov, L.N. Bolshev, professors V.V. Nalimov, Yu.K. Moreover, we are not only talking about the 20th century. They forgot about Academician M.V. Ostrogradsky, who should be considered the founder of the theory of statistical control (not

[1]https://rosstat.gov.ru/free_doc/new_site/rosstat/stbook11/book.html

only in our country, but throughout the world). His 1846 report on this topic, generated by the needs of supplying the army, was published in 1848 [18].

The state of the "Rosstat" branch of statistical science should be considered extremely unsatisfactory. The separation of this messageThe results of the work of the last century are striking. But the attempt of the 1980s to unite the two branches of statistical science, expressed in the creation of the All-Union Statistical Association in 1990, gives hope [19]. Unfortunately, as a result of the collapse of the USSR, this public organization ceased its activities. It should be restored.

Conclusion

The most important task at the present stage is the wide dissemination of information about the revolution in mathematicsand statistical research methods and the scientific results obtained in accordance with it based on the modern paradigm. Both theorists and applied scientists should, at a minimum, know this information, and, at a maximum, apply new results in their work. It is necessary to fight the remnants of the past. At the same time, it is necessary to see the place of the results obtained during the revolution among the judgments based on the diversity of new terms. The relationship between artificial intelligence, neural networks, big data and mathematical research methods is discussed in [2024. No. 201. P. 266-288].

It is important to further develop requirements for statistical methods of data analysis [2022. No. 181. Pp. 316–343], ensuring their compliance with the modern paradigm. At the same time, it is necessary to avoid errors caused by the low qualifications of persons preparing certain regulatory documents. We encountered a similar situation when analyzing state and international standards for statistical methods of quality management in the 1980s. As established by the Working Group of 66 specialists (15 doctors and 36 candidates of science),

several dozen of them contained gross errors and were eventually canceled[2]. About these events It is absolutely indisputable that it is necessary to rely on scientific results, and not on erroneous materials, even if they are called GOSTs (especially since in modern conditions any GOSTs are not mandatory). Doubtful GOSTs and similar materials must be analyzed and, if errors are found, cancelled. Unfortunately, the analysis of such texts requires a lot of time from qualified specialists. Due to the lack of an appropriate organizational structure and the necessary resources, such an analysis has not yet been carried out with respect to a number of normative and technical documents, and such materials, unfortunately, are in effect.

Changes are needed in the teaching of courses on mathematicsand statistical research methods, with the aim of ensuring their compliance with the new paradigm. A number of textbooks needed for this have already been published by us in 2003–2024.

Obviously, serious organizational efforts are needed to implement the program outlined above. Work experience "Scientific Journal of KubSAU", briefly described above, allows us to confidently predict the further development of the scientific revolution in the field of mathematical and statistical methods in economics. There is no doubt that its tasks will be accomplished.

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