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From Typical Areas to Random Sampling: Sampling Methods in Russia from 1875 to 1930

Martine Mespoulet

University of Angers, France. E-mail: martine.mespoulet@wanadoo.fr

Argument

While we know that Russian mathematicians contributed to the application of probability in the theory of statistics, Western literature on the history of statistics generally overlooks the role played by statisticians working in *zemstva* statistics departments. This paper argues that the quantity and the diversity of statistical data needed by *zemstva* administrators stimulated methodological innovations in the field and influenced the rise and development of sampling surveys in Russia between 1875 and 1930. The first surveys on parts of the whole were done by statisticians who were seeking solutions to practical administrative problems, and their sampling techniques evolved as Russian administrators put these statistical surveys to use. Finally, the paper argues that Kovalevskiy's mathematical treatment of the theory of stratified sampling, published in 1924, ten years before Jerzy Neyman's, is in fact a synthesis of the *zemstva* statisticians' sampling practice and the Russian university statisticians' theoretical works before 1917.

The study of the practice of sampling surveys in Russia between 1875 and the end of the 1920s cannot be separated from an analysis of the different stages of statistical administration in that country. Russian textbooks on statistics usually state that the first survey on parts of the whole was carried out in 1875 by a provincial agency of the Tsarist State Central Statistical Committee (TsSK – *Tsentral'nyi statisticheskiy komitet*). In actual fact, such surveys were being undertaken at the same time in other TsSK local agencies as well. However, most of the surveys on parts of the whole conducted in the 1880s were carried out by a different kind of provincial statistical agency, *zemstva* statistics departments. *Zemstva* were elected bodies of local self-government in the European part of Russia (Emmons and Vucinih 1982). They were created in 1864 and abolished at the end of 1917. Their statistics departments played a leading role in the practice and methodology of sampling surveys in Russia (Mespoulet 2000).

How can these first forms of sampling surveys and their development until the end of the 1920s be characterized? How did administrative needs and discussions between statisticians play a role in the process of improving sampling methods during this period?

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This paper will give an account of the first outlines of these surveys in the 1880s and will review the main concerns of Russian statisticians in relation to sampling. It will focus on the contribution to the theory of sampling by A. G. Kovalevskiy whose mathematical treatment of the theory of stratified sampling that was published in 1924 – ten years before Jerzy Neyman's – can be considered a synthesis of *zemstvo* statisticians' sampling practices and Russian university statisticians' theoretical works before 1917.

A Use Generated by Administrative Needs

In Russia, as in other European countries, the first sampling surveys came into being because it was impossible for the State statistics administration to carry out censuses or exhaustive surveys throughout a given territory every time they had to collect quantitative information that they needed in order to work out economic and social measures.

In the Beginning was the "Type"

A response to this problem was first provided as early as the middle of the 1870s when the Terek local agency of the TsSK, located in the Cossack province, carried out a survey on only some parts of its administrative territory because it lacked any means for conducting a comprehensive survey. To this end, TsSK statisticians selected certain villages that they described as "typical" because their characteristics were considered to be average in comparison with the whole mass of villages (Gur'yev 1921).

A village considered typical had most of the characteristics common to the villages located in a circumscribed area. Just like the "average" village, a "typical" village could be considered the image of similar ones that form the largest part of the totality of the villages in the area surveyed. In fact, the method used to select a "typical" village was a result of material constraints rather than theoretical choice.

The Terek administrative territory was divided into four homogeneous areas. A few villages were selected from each of the four areas, though not in equal numbers. Statisticians selected six villages from each of the poorest areas and only two from each of the others. Increasing the number of cases studied in the poorer areas was intended to magnify the characteristics surveyed in order to determine with greater accuracy the reasons for the poverty in the population. The same questionnaire was used to interview each household in each village selected.

This first known attempt by an administration to conduct surveys on some parts of the whole was carried out between 1876 and 1881. At this time the concept "average" was associated, more or less clearly, with the idea that one could correctly generalize the results of partial surveys to the whole population. The aim of these investigations was to improve the understanding of the conditions under which the

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Cossacks lived. In fact, this aim was similar to that of ethnographic surveys carried out in Russia in the second half of the nineteenth century.

Zemstvo Statisticians and Sampling Surveys

Subsequent surveys conducted in the 1880s were also generated by administrative needs. But they were carried out mainly within the framework of another institutional environment, in the statistics departments of *zemstvo* local self-government bodies. The Statute of 1864 introduced this new kind of local administrative institution which was entrusted with the management of some mandatory services, such as social welfare and food supply, and other services, such as health and education. In these latter fields, *zemstva* had some freedom of action (Emmons and Vucinih 1982). In order to gather the quantitative information that they needed for administration, these new territorial institutions engaged statisticians and conducted many surveys throughout their territories (Johnson 1982; Mespoulet 2001). However, faced with the human and financial cost of conducting such surveys throughout the territory in one *zemstvo*, the statisticians decided to conduct surveys only in some parts of it. This practice was pursued until the abolishment of *zemstva*.

The first sampling surveys organized by *zemstvo* statistics departments in the second half of the 1880s were carried out as a complement to household inventories (*Podvornye perepisi*). These comprehensive surveys had two objectives. On the one hand, in order to address the economic and social needs of their locale, *zemstvo* institutions had to organize extensive surveys to find out the social and economic living conditions throughout their administrative territory. For that purpose, the survey questions in household inventories related to economic activity in the different households. Various questions about grain stocks and the frequency of fires in farms and villages were included. The statisticians added questions about social characteristics, for example about the composition of the households and the educational level of their members. On the other hand, *zemstvo* institutions had to collect taxes to finance their expenses. Thus, the second aim of household inventories was to gather information to help assess property for taxation purposes.

Until the end of the 1890s, sampling surveys were carried out mainly in order to analyze various phenomena in-depth, so as to complement household inventories. Observing the details of selected households ought to provide a better understanding of the organization of peasant farms and the agricultural production system. This worked particularly well when peasant budget surveys were first conducted toward the end of the 1880s. A little later, at the end of the 1890s, sampling surveys began to be used to analyze the evolution of peasant households and social differentiation in the countryside in the framework of what was called "dynamic surveys." After 1905, sampling surveys found a new field of application: estimating crop yields (Svavitskiy 1961). In some *zemstva*, these surveys were used to study the elements of peasant farms' fixed capital. In the Moscow and Tver' provinces, work hours in agriculture

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were calculated on the basis of the results of the sampling surveys. In that case, as in the case of all the sampling surveys carried out since the 1880s, constructing samples was a task for qualified statisticians. Interviewers had to apply the instructions given by their *zemstvo* statistics agency to the letter.

At the end of the 1890s, in some *zemstva*, sampling surveys began to substitute for comprehensive surveys, particularly in the period between two comprehensive inventories. The aim of sampling surveys was to study the changes in peasant households from one inventory to the next. This method was discussed at the Statistical Conference organized in February 1898 by the Statistical Committee of the Moscow Juridical Society.

The Role of the Moscow Juridical Society

The development of sampling surveys in *zemstvo* statistics departments benefited from the action of the Moscow Juridical Society, headed by A. I. Chuprov (Tschuprow). From its inception in 1882, this scientific society attempted to homogenize the programs and methods of statistical surveys conducted throughout the Russian territory (Svavitskiy 1961). This project was finally carried out in 1887. A commission was entrusted with the task of elaborating basic principles to standardize the methods of gathering statistical data throughout the various regions of Russia. In particular, it indicated how to organize partial surveys in *zemstva* and when to use them in preference to comprehensive ones.

Surveys into one part of the whole were recommended as a complement to, but not as a substitute for, comprehensive surveys. They had to be organized on the basis of a sample built with a reasoned procedure. To this end, statisticians had to use the data from a previous census. The aim was to thoroughly analyze the economic and social characteristics of a given area, most of the time from a comparative perspective, in order to study social and economic differences in the countryside. Thus, the crucial task was to define homogeneous typical areas and select "typical villages" from these, in order to highlight the differences among the areas. As a result, questions regarding the process of delimiting homogeneous areas, and the conditions necessary to generalize results obtained from parts of the whole were to become a central topic in methodological and theoretical discussions among *zemstvo* statisticians.

The statistical conference held in Moscow later in 1887 approved the commission's recommendations and clarified the meaning of "typical characteristic." A typical village of an area had to include "the most important economic characteristics and the specific characteristics of each different area" (Gur'yev 1921). However, the conference did not indicate precisely how to define typical characteristics so that a whole group of villages in one area could be replaced with one village that would provide an image of the whole group. Nor was there any guidance as to the number of units to select. As in other European countries, the debate about the definition of the concept of representativeness came later on during the period 1895–1925. For

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Russian statisticians as well as for their European colleagues, these first surveys about a part of the whole did not challenge the theoretical ideal of the comprehensive census.

The Development of Monographic Surveys

The first *zemstvo* surveys of a part of the whole were monograph-type surveys of typical villages chosen for their average characteristics compared with the totality of the villages in their given area. At the ninth congress of Russian naturalists and physicians held in 1894, the use of monographic surveys was a central topic of discussion (*Trudy* 1894). Chuprov presented an important paper on this topic. In particular, he dwelt on the idea that the study of a small number of villages could provide knowledge about the totality only if these villages were selected on the basis of data gathered in a previous comprehensive survey. The necessary condition was that the characteristics of the selected villages were as close as possible to the average villages in the area. Thus, "type" was strongly correlated with "mean" (Lositskiy 1925).

However, the use of monographic surveys by Russian statisticians differed from that of Le Play or of Cheysson. As Chuprov himself pointed out, the right to generalize results was a crucial issue. That is why – like other Russian statisticians – he criticized Le Play's method of selecting the cases studied. Chuprov believed that the intuition of researchers was not sufficient; the process of selecting typical households had to be carried out by way of a reasoned procedure on the basis of data collected in a previous census. Chuprov, however, went further and suggested using monographic surveys in their own right, namely without the help of a previous complete enumeration to select the units surveyed.

In this case, the sole condition was the possibility of choosing one or a small number of typical villages in each rural area. To this end, the typical characteristic was determined on the basis of the crops and the quality of the fields or the climatic conditions of the investigated area. Although this idea was not worked through at this congress, a first step was made toward studying only one part instead of studying the totality. However, soon the issue of using sampling surveys instead of a census would open up a sequence of doubt and discussion. Since the middle of the 1880s, the use of monographs has been the preferred method for *zemstvo* budget surveys.

Monograph Budget Surveys

The aim of monograph budget studies of peasants was to provide clues to more accurately understand the organization of agricultural production and living conditions in peasant households. To this end, *zemstvo* statisticians compiled very detailed data on the income and expenses of each family by means of a standard

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questionnaire. *Zemstvo* budget surveys in the 1880s and the 1890s are associated with F. A. Shcherbina, who headed the Voronezh *zemstvo* statistics bureau from 1884 to 1903 and organized his first budget survey in 1885.[1] Some budget studies were carried out before the 1880s, for example in 1846 by D. P. Zhuravskiy and in the 1870s by P. P. Semënov Tian-Shanskiy. But Shcherbina was the first statistician to undertake a systematic application of these surveys as an instrument to study peasants – their household conditions, the conditions of agricultural production, and their living conditions. To do so, he elaborated a methodology for this kind of survey.

The Voronezh budget studies were based on a sample incorporating a small number of farms selected on the basis of data provided by previous comprehensive inventories (Shcherbina 1900). Each statistician had to work four full days with the same family, eight to ten hours a day. Consequently, only 230 household budgets were surveyed in the province of Voronezh between 1887 and 1896. Other budget surveys were carried out during the same period or later on in other *zemstvo* statistics bureaus, in particular in the provinces of Vologda, Kaluga, Kostroma, and Kharkov.

Though it was a survey about a part of the whole, in the statisticians' view the monographic method enabled them to understand the totality because it was concerned with the type, which embodied a population's average characteristics.

Discussions among Statisticians about Random Sampling

Step by step, *zemstvo* statisticians proceeded from the choice of typical units to the use of more elaborate methods. At all the Russian statistical conferences since the 1890s, sampling techniques and the choice of variables were widely discussed by practitioners from administrative statistics services and theoreticians from universities, such as A. I. Chuprov. During these conferences and congresses, both practitioners and theoreticians compared and discussed the different methods. The methodology used and the results of the surveys carried out in different *zemstva* were compared in order to generalize from the experience acquired. New methods for collecting and processing statistical information were presented and recommended. They were then tried out in the field before being assessed at the next congress. Thus, in Russia, the methodology of sampling surveys was developed from the practice of regional administrative statistical surveys and was fed by the theoretical principles worked out and discussed in Russian statistics societies and at congresses (Mespoulet 2000).

Actually, the first methods for sampling that relied on random selection were carried out by the Tsarist State statistics administration. Aleksandr A. Kaufman conducted sampling surveys in Siberia for the Ministry of Agriculture between 1887 and 1890 (Kaufman 1922).[2] He was the first in Russia to carry out a sampling survey

[1] Fëdor A. Shcherbina (1849–1936) emigrated in 1920. Since 1922 he lived in Prague where he taught statistics first at the Ukrainian University and then at Prague University.

[2] Aleksandr A. Kaufman (1864–1919) became in 1907 professor of statistics at the Saint Petersburg Women High Courses, renamed University of Petrograd in 1918.

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instead of a census. In this instance, the sampling survey was not seen as a complement to a census carried out in a parallel direction. Kaufman did not use a unique and homogeneous form of random selection at this stage. On the one hand, the proportion of selected households varied from one-fourth to one-sixth according to the different rural cantons (*volosti*); on the other hand, the mechanical method of sampling was associated with a method using a reasoned procedure.

According to A. A. Gur'yev (1921), the first random sampling surveys *stricto sensu* was carried out in 1896 in the Kaluga *zemstvo* by head of the statistics office, A. V. Peshekhonov.[3] Because it was impossible to organize a great number of peasant budget studies in the Kozel rural district, the statistician decided to select every tenth household from the list drawn up by the head of the village (*starosta*). Once again this method was a consequence of constraints imposed by conditions and was not made by choice. Peshekhonov decided to use the random sampling because there was no previous data upon which to build a sample by reasoned procedure. Although this first kind of random sampling was due to necessity rather than theoretical choice, it marked a decisive step in the spread of sampling surveys in Russia. The link with the census was severed. However, there was still no break with the practice of selecting typical units. Peshekhonov himself believed that the method he used would "warrant the typical characteristic" of selected households (Peshekhonov 1898).

Besides Peshekhonov's approach, other sampling methods were applied in different *zemstva* at the end of the 1890s. Generally speaking, the years 1894–1914 were marked by various successive attempts to improve sampling methods. In particular, we must mention different experiments of multi-degree sampling surveys carried out after 1900. The best known are the three-degree sampling surveys carried out by the Viatka *zemstvo* from 1900 to 1902 and V. G. Groman's[4] five-degree survey, including a three degree sample, carried out in Penza *zemstvo* during the years 1911–1913 (Kaufman 1922). In both these cases, the selection of units was made on the basis of a reasoned procedure, combined with a random selection.

At the Statistics Congress held in 1910, Groman tried to justify theoretically the necessity of combining different methods (i.e., sampling, the monographic method, and the census) when conducting a survey. He believed that statisticians had to use the most relevant method at each level of the survey, according to the use of data. In Groman's view, each method had to be chosen in connection with the kind of factors being studied (*Trudy* 1912).

After 1900, discussions at Russian statistics conferences focused on sampling methods. They connected more and more questions related to the practice of administrative statistics with the most recent contributions of statistical theory. More and more *zemstvo* statisticians tried to apply mathematical principles to the practice of

[3] Aleksei V. Peshekhonov (1867–1933) was Minister of Food in the Provisional Government during World War I.

[4] Vladimir G. Groman (1874–1940) became one of the main economists of the *Gosplan* in the 1920s.

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sampling. A. A. Chuprov[5] played a predominant part in this process. In particular, he was one of those who, following Bortkevich (Bortkiewicz),[6] studied the question of the representativeness of samples. As his father had done a few years earlier, he established a link between university mathematical statistics and *zemstva* administrative statistics by participating in statistics commissions at various congresses of Russian naturalists and physicians. At the 1900 conference, he submitted a report on the principles of random sampling. At the congress held ten years later, he contributed a more detailed paper on this topic and addressed issues dealing with the measure of precision of the estimators. Moreover, he raised theoretical questions about selecting stratified samples (*Trudy* 1912). In particular, he insisted that it was best to start by splitting the whole into different parts, which should be as homogeneous as possible. He added: "The observation will be carried out only within the limits of such parts on the basis of the method of sampling." Moreover he stated that this method seemed theoretically sound, but that there still remained some unsolved questions about implementing it. In fact, this problem was resolved later on, after World War I and the Civil War, precisely by A. G. Kovalevkskiy in 1924.

Kovalevskiy pursued A. A. Chuprov's reflections on stratified samples. He also used contributions to the development of the theory of statistics in Russia in the 1910s made by of S. S. Kon[7] and N. S. Chetverikov.[8] Both had been students of A. A. Chuprov. Kon's work during World War I was really innovative (Kovalevskiy 1924). The Ministry of Agriculture had entrusted Kon with processing the 1916 agricultural census data. It was the first all-Russian agricultural census and, for the first time in Russia, a sampling survey had been organized as a complement to a general census. Two samples were selected mechanically, one with 3 per cent of the farms and the other with 2 per cent. Due to conditions of war, processing the census data went very slowly. So Kon decided to organize these operations only on the basis of a sample of the collected blanks (Kon 1917; Chetverikov 1920). The landholding cards were selected mechanically. The same method was applied to the 1917 agricultural census data.

Kovalevskiy's Contribution to the Method of Stratified Sampling

A Watershed in Russian and Soviet Statistics

Although his name is hardly known in western countries and he is rarely quoted in Russian statistics books, Kovalevskiy was one of Russia's most innovative statisticians

[5] Aleksandr A. Chuprov (1874–1926) was A. I. Chuprov's son.
[6] Vladislas I. Bortkevich (1863–1931) left Russia for Germany in 1901.
[7] Stanislas S. Kon (1888–1933) emigrated to Paris in 1921 and then lived in Prague. There he taught the theory of statistics at the Russian Juridical Institute.
[8] Nikolai S. Chetverikov (1885–1973) was at the head of the Department of methodology of the Soviet Central Direction of Statistics in the beginning of the 1920s.

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in the 1920s. His most important contribution is the mathematical treatment of the theory of stratified sampling, which preceded J. Neyman's by ten years. His book, *Foundations of the Theory of the Sampling Method*, was published in Saratov in 1924 (Kovalevskiy 1924). It bears witness to the high level of theoretical thinking on sampling methods in Russia at that time.

From various points of view, Kovalevskiy's work marks a watershed in Russian and Soviet statistics. Born in 1892, he was not a *zemstvo* statistician. On the contrary, he acquired a mathematical education during his student years rather than statistical practice in the field. In 1916, he defended his first thesis at the mathematics faculty of Kazan University, where A. A. Ovchinnikov taught statistics and probabilities. After university, Kovalevskiy left Kazan for Saratov. At first he worked in the co-operative movement. In 1917, he was the head of the statistics office of Saratov Union of consumer co-operatives. In July 1921, he joined the regional statistics office of the Soviet Central Direction of Statistics (TsSU – *Tsentral'noye statisticheskoye upravleniye*), where he worked as head of the demographic section. In 1924, he became professor of statistics at Saratov University. Until his death in 1933 he had a dual career (Mespoulet 1999).

Thus his career in statistics marked a junction of the university and the state statistics administration and mathematical theory of statistics and administrative statistics. From this point of view he was an heir both of *zemstvo* statistics and of academic statistics. It is not surprising, therefore, that his theoretical work on sampling methods takes into account questions relating both to survey practice and to the principles of probability theory. His mathematical treatment of the theory of stratified sampling bears the stamp of this dual influence.

A Context of Statistical Effervescence after 1917

In order to better understand the importance of Kovalevskiy's theoretical and methodological innovations, we have to view them in the scientific context of the first half of the 1920s, as well as in the institutional and political environment of administrative statistics of that period.

Questions about the representativeness of a part of the whole and about the conditions required to generalize the results of a sampling survey had already begun to be answered in Europe in 1901, with Kiaer's report to the Budapest International Statistics Congress, and in Russia at the end of the nineteenth century with Bortkevich's work on applying probability to sampling, and at the beginning of the twentieth century with A. A. Chuprov's work. We must also mention how Chuprov and his students were influenced by Andrey A. Markov (1856–1922).

However, at the beginning of the 1920s, the main focus of discussion among statisticians was the same as at the end of the nineteenth century: how could mass phenomena be studied by means of surveys on a part of the whole without losing the totality of the data provided by a census or a comprehensive survey? The problem was

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that, in spite of their theoretical attraction, it was simply not possible to organize such comprehensive surveys each time they were needed by the Statistics Administration. Another problem was that, in addition to their human and financial cost, the censuses conducted in the first years of the Soviet Central Statistics Administration were characterized by a low scientific output – a fact often pointed out by regional offices.

In particular, because censuses of many different types where carried out frequently, it was impossible to make proper use of the data collected. This situation also led to another problem: by the time the census results were finally available, they no longer provided an accurate picture of the prevailing situation. They were too late and therefore were not useful as a basis for influencing state decisions on economic and social matters. Administrative correspondence between the heads of TsSU regional offices and their central directorate indicates that the multiplication of surveys was parallel to the increase in the number and the variety of censuses – a situation which generated overload and fatigue for the majority of the statisticians working in the regional offices. The situation was exacerbated by growing difficulties in connection with the Civil War and, since the end of 1921, by the reduction of the staff in the whole TsSU. The "statistical enthusiasm" of the first three years gave way to despair. The only solution was to adopt sampling surveys.

However, even for a statistician as convinced as Kovalevskiy of the necessity and advantage of sampling surveys, this method still had its own limitations. In particular, he thought that sampling surveys did not easily serve the study of social phenomena. In contrast to natural phenomena, social phenomena had certain characteristics that did not always allow a sampling survey. The need to investigate diversity was the main obstacle. For Kovalevskiy, however, a sample was adequate for the different forms of calculation that enabled one to show the similarities and differences between the different parts of an aggregate. Nevertheless, the question remained: how to reconcile – with the greatest accuracy possible – a random method of selecting the units of a sample and the need to study the diversity of a population; and, consequently, how to take into account its sub-groups whose characteristics were already known. At the beginning of the 1920s, this issue still prevented the widespread application of sampling surveys. In 1924, Kovalevskiy's mathematical treatment of stratified sampling solved the problem.

A Theoretical Treatment of Stratified Sampling

Above all, Kovalevskiy's work was innovative because it enabled mathematical treatment of the optimum allocation of the sample among different strata in a stratified population. The first characteristic of his method is the process of selecting a sample within the population. In order to survey a population characterized by diversity and by a high dispersion of the studied character, one has to form fairly homogeneous strata in order to estimate as accurately as possible the parameters of the

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population on the basis of a previously calculated estimate on the different strata. In this instance, the optimum allocation of the total size of the sample is attained when the sample sizes of the different strata are proportional to the numbers of units in each stratum and the degree of variation of the studied character in each. The second characteristic of Kovalevskiy's method is the use of mechanical selection without replacement for sampling.

Although he saw his own work as the continuation of the work of Bowley and Russian statisticians, Kovalevskiy at first criticized some points in Bowley's contribution. In his opinion, Bowley's theory was not sufficiently adapted to the statistical study of social phenomena, especially as it laid down one condition which was difficult to comply with in the case of a survey of a population: the condition of a selection with replacement. Moreover, Kovalevskiy considered that random selection was a constraint which would be impossible to observe in the case of a social survey. That is why he suggested using a mechanical selection. According to him, this method would guarantee not only an "objective" selection of the units of a sample, but also their regular distribution "over the whole continuum of the general aggregate."

He nevertheless drew a distinction between a mechanical selection and a random selection (*sluchaynyi otbor*). He asserted that the expression "random selection" should be used only in the theoretical case of a selection in which "nothing limits the free action of randomness." In that sense, he associated the expression "random selection" with a lottery draw (*po zhrebiyu*) and not with a mechanical selection:

> To allow an objective measure of precision (of results), the selection of the units of the sample group must be carried out using a method which guarantees a lack of orientation or arbitrariness. A mechanical selection and a lottery-draw type of selection of units (*po zhrebiu*) or random selection, are, for example, such methods. In the case of a mechanical selection, there is no element of chance; that is why, when it is applied, the measure of precision of results cannot – without any hypothesis – be carried out on the basis of the probability theory. It is completely different in the case of random selection. With random selection, all depends, so to speak, on freak chance and consequently it is possible *a priori* to consider that such a measure can be carried out. (Kovalevskiy 1924, 25)

In fact, Kovalevskiy used the expression "random selection" for a random selection with replacement and the words "mechanical selection" for what we now call random selection without replacement.

In his view, selection without replacement offered two advantages. On the one hand, according to the work of Chuprov, Markov, and Kon, getting a given degree of accuracy for an estimate depends not only on the sample size, but also on the sampling percentage. According to Kovalevskiy, it is therefore necessary to determine mathematically the optimal sampling percentage. On the other hand, formulas of estimation of errors used in the case of random selection can be adapted to

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mechanical selection for, "in that case the most accurate results are obtained precisely by means of mechanical selection and not of random selection." Kovalevskiy then tried to demonstrate mathematically the superiority of mechanical selection over random selection on the basis of the study of the distance of the variables to the mean in each case.

In particular, he showed that a mechanical selection without replacement was more precise, i.e. that it contained a lower risk of error than a selection with replacement because the variance of the sample built in this way was minimized. Consequently, he decided to use mechanical selection without replacement. Though aware that this method was mathematically more complicated, he nevertheless considered that this formula resulted in a more accurate estimate. Stratified sampling strengthened the degree of precision thus obtained.

The originality of Kovalevskiy's argumentation is that it associated mechanical selection without replacement with stratified sampling on the basis of the division of a heterogeneous population into a number of homogeneous strata. In this way he restored to these strata the necessary conditions allowing the use of mechanical selection while following conditions of representativeness as in random selection. In fact, the idea of dividing a heterogeneous population into homogeneous strata was a legacy from the typical method. When Kovalevskiy carried out such a methodological choice, he retained the link, which seems characteristic of Russian statistics at that time, between the idea of representativeness and the idea of type. He thus integrated the practice into a mathematical formulation.

From this point of view, Kovalevskiy's work seems to be a synthesis of the application of probability calculus to statistical theory and the contribution of the *zemstvo* statisticians' sampling practice. At the junction of two eras in statistics, Kovalevskiy belongs to the group of Russian statisticians who undertook the transition from a conception of statistics that was highly connected to field practice to a more mathematical conception, and who led the way from one configuration of the production of statistical data to a new configuration.

Conclusion

Kovalevskiy's theoretical contribution to stratified sampling illustrates the vitality of the theory and practice of sampling methods in Russia in the 1920s. This decade marked the end of a period that began in the 1880s, a period which now seems to have been the golden age of sampling surveys in Russia.

In a paper published in 1956, S. S. Zarkovich dwelt on the fact that, in his view, "during the First World War and in the period immediately following it. . . it was precisely in Russia that the most intensive work in the field of sampling was being carried out" (Zarkovich 1956, 336). This situation was in great part due to the expansion in the use of sampling surveys in the Soviet Statistics Administration after October 1917. In a context of "statistical enthusiasm" the beginning of the 1920s

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was marked by an effervescence of statistical data production in the Bolshevik Statistics Administration and by a great increase in the number of censuses and sampling surveys. Since 1920, the sampling survey has become the predominant method of investigation in present-day statistics, for example, in current surveys on crops.

As in the pre-revolutionary period, dynamic agricultural surveys were used to study economic transformations and the evolution of social differentiation in the country. Samples were determined in two stages. First, typical villages were chosen by way of a reasoned procedure in circumscribed areas, secondly households were selected mechanically. During the 1920s this method was applied to other fields, for example the observation of population dynamics. The application of household budget surveys was extended to other social categories in the population, in particular to workers and employees. Another kind of sampling survey had been developed in pre-revolutionary Russia: during World War I, the Provisional Government needed information about nutrition and encouraged statisticians to carry out food consumption surveys. After October 1917, this experience helped the Bolshevik Statistics Administration to efficiently organize such surveys from 1919. Its department of food consumption led by Lositskiy[9] used to carry out two sampling surveys each year. Households were selected by a mechanical method. Within the framework of a planning process, these data were used to elaborate the balances of production and consumption of agricultural products. When food consumption surveys were suppressed in 1928, the national sample was composed of 10,000 urban households and 25,000 peasant ones.

So, though the use of sampling surveys had already spread within the framework of *zemstvo* statistics departments, it had greatly expanded in the 1920s in order to cater to the needs of the new Soviet State Administration. Although the representativeness constraint for sampling had become a central concern for all statisticians, discussions about the respective advantages of random selection and of a selection led by way of a reasoned procedure nevertheless remained lively. It was difficult to relinquish control and let randomness take over. At the end of the 1920s, when the Communist Party began to have a hand in this issue, the political use of statistical data tended to darken the debate. It rang the knell of the golden age of sampling surveys in Russia.

Although he was one of the TsSU's best statisticians, Kovalevskiy's contribution to the method of stratified sampling was not applied by the Soviet Statistics Administration in the 1920s. In 1936, his work was not quoted in the chapter devoted to sampling surveys in the main statistical handbook published by TsSU (Boyarskiy et al. 1936). The authors wrote only about "typical stratification" (*tipicheskoye raionirovaniye*). According to this method, the strata were constituted on the basis of some "typical criteria," and not by mechanical selection or random

[9] Aleksander E. Lositskiy was the main specialist of nutrition statistics during the First World War. As the head of the statistical department of the Ministry of Food he began building a mass network of food consumption investigations.

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selection (*stricto sensu*). Among the criteria used, we can mention the importance of "economic sectors" and "social groups." In actual fact, the new political context of the 1930s shaped a different kind of statistical reasoning, with a new concept and use of stratification in sampling.

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