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THE CHOICE OF A SAMPLING PROCEDURE FOR A (TOO) SMALL TARGET POPULATION: THE CASE OF CROATIAN PUBLIC HOSPITALS

IZBOR PRISTUPA UZORKOVANJU IZ (PRE)MALE CILJANE POPULACIJE: SLUČAJ HRVATSKIH JAVNIH BOLNICA

ABSTRACT: In some cases, a sampling approach must be used instead of a census even if the target population is small. In such a case, the drawn sample will also be small and every sample unit can significantly influence the results. This paper aims to address the aforementioned issue from the perspective of different sampling procedures. The observed small population consists of 57 Croatian hospitals. The averages of total due obligations for medicines of Croatian hospitals in 2014 are estimated using three different sampling procedures and compared to the real population parameter value. The analysis has shown that the minimum recommended overall sampling rate, which would result in satisfactory precision and accuracy levels of parameter estimates, for simple random sampling and stratified random sampling is 70%. The two-stage cluster sampling procedure, on the other hand, did not achieve a satisfactory precision and accuracy level at any of the observed sample sizes because of a high level of heterogeneity between clusters.

KEY WORDS: complex survey design, sampling, clustering, stratification, Croatian hospitals.

JEL Classification: C13, C83, I10.

SAŽETAK: Premda je ciljana populacija mala, u određenim slučajevima je umjesto cenzusa potrebno koristiti uzorkovanje. U tome slučaju, budući da se bira iz male populacije, veličina izabranoga uzorka je također mala. Posljedično, svaka jedinica u uzorku ima

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značajan utjecaj na rezultate. U radu se ističe navedeni problem te se razmatra s gledišta različitih pristupa uzorkovanju. Malu populaciju koja se koristi u istraživanju čini 57 hrvatskih bolnica. Prosječne vrijednosti ukupnih dospjelih obveza za lijekove u hrvatskim bolnicama u 2014. godini dobivene pomoću triju različitih pristupa uzorkovanju se uspoređuju sa stvarnim vrijednostima. Ako se žele postići zadovoljavajuće razine preciznosti i točnosti procjena, analiza je pokazala da bi tada u slučaju jednostavnog slučajnog te stratificiranog slučajnog uzorkovanja trebalo u uzorak izabrati najmanje 70 % populacije. S druge strane, zbog visoke razine heterogenosti između skupina, nije bilo moguće ostvariti zadovoljavajuću razinu preciznosti i točnosti procjena kod niti jedne promatrane veličine uzorka korištenjem uzorkovanja po skupinama.

KLJUČNE RIJEČI: složen dizajn ankete, uzorkovanje, grupiranje, stratifikacija, hrvatske bolnice.

1. INTRODUCTION

Health care is a public service of special public interest that organizes work in health care institutions (public and private), collective or individual private practices. The concept of health is narrower than the concept of health care as the latter concept also includes the activities taking place within health institutions and other measures required to preserve and improve health which are carried out by other sectors of the population as a whole (Dražić Lutilsky, Žmuk, Budimir, 2016).

In Croatia, health care is provided in the entire territory and is aimed at the entire population. According to the Law on Health Care (Official Gazette, 2008), on the territory of Croatia, health care is carried out at four levels: primary, secondary, tertiary and at the level of health institutes. For the purposes of this paper, our focus is on hospitals, institutions dedicated to carrying out activities on the secondary and tertiary level. Health care institutions at the secondary level are clinics, hospitals and spas. Health care institutions at the tertiary level of health activities are clinics, hospitals and clinical hospital centres. At the secondary and tertiary level, there are altogether 57 health care institutions in Croatia.

Although hospitals are very important for a society, their number remains relatively small. There are many reasons for that. Above all, it is necessary to highlight economic reasons. Namely, while hospitals are primarily non-profit oriented institutions, the costs of their building and maintenance are rather high. Administrative and non-administrative costs should be also taken into account. The main social reason for keeping the number of hospitals down is the size of population. The smaller the population of a country is, the fewer hospitals are needed. Similarly, the size of a country and its geographical position also has a great impact on the number of hospitals.

However, since hospitals and the hospital system are very important in every country, their work and functionality should be constantly monitored. This can lead to significant improvements in the existing healthcare system, i.e. to better healthcare for the citizens. Furthermore, the collected data can improve hospitals' budget planning for the future. In the case of public hospitals, budget planning is very important as there is a fixed amount of money to be divided among all hospitals in the public sector. Moreover, careful budget planning is crucial as the total budget for public hospitals is rarely big enough to fulfil the needs of all hospitals. Still, this paper is not going to deal with the problems related to the lack of funds for public hospitals. In this paper, the focus is on the collection and evaluation of the data needed for budget planning and business decision making in the hospital system.

Although the number of hospitals in Croatia is relatively small, it can be very hard to obtain the necessary information from all of them due to time constraints or other reasons. Consequently, a sampling approach has to be used. Since the population size, i.e. the total number of hospitals, is rather small, the sample size, i.e. the number of sampled hospitals, is going to be even smaller. As a result, the data from each sampled hospital can significantly influence the results of the survey. Moreover, the sampling method used could also have a significant impact on the survey results.

The goal of the paper is to investigate which sampling procedure tends to have better properties when sampling units from a small population. In order to do that, Croatian health care institutions' data are used only as an example. In other words, an analogous analysis could be made on any other small population case.

We will attempt to answer two research questions. First, how large a sample should be taken if the population is relatively small? Second, which sampling procedure shows better performance in that case. To answer these research questions, the authors have set two research hypotheses. The first research hypothesis is that in case of small populations, in order to get satisfactory precision and accuracy levels of parameter estimates, at least 50% of population units should be sampled. The second research hypothesis is that for the same sample sizes, stratified random sampling achieves, on average, more accurate results than simple random sampling and two-stage cluster sampling.

Since the paper focuses on problems related to sampling of small populations, it may be necessary to emphasize that the topic should not be confused with small area estimation. Namely, according to a definition, a small domain or area refers to a population for which reliable statistics of interest cannot be produced due to certain limitations of the available data (Hidiroglou, 2007). This is unlike the topic of interest in our paper as we deal with populations which have a relatively small number of units. For more information about small area estimation see the work of Rao and Molina (2015).

The paper is organized as follows. After the introduction chapter, the second chapter briefly discusses the financial characteristics of the Croatian hospital system. The third chapter presents the basic characteristics of the three observed sampling procedures. The observed data and used research methods are presented in the fourth chapter whereas the fifth chapter brings a detailed analysis of the results and discussion. In the final, sixth, chapter conclusions and recommendations for future research are given.

2. CROATIAN HEALTH SYSTEM FUNDING

The funding of health care is central for the functioning of the health system. However, it is not possible to find two countries that have exactly the same system of funding health care. In order to understand the present system of funding health care, one should have a knowledge of its historical development, the unique conditioning attributes affecting its development and support in a specific country. These attributes feed into national traditions of health care funding and affect the present system of financing.

According to World Health Organization (2013), a complete coverage of health means that everyone has access to quality health services they need without the risk of financial difficulties for the payment of such services. In order to achieve that, a country needs to build a powerful, efficient, well-managed health care system; enable access to essential drugs and technologies; and provide a sufficient number of motivated health workers. However, it is very challenging to reach the appropriate level of health care services with limited resources. Consequently, the health system in Croatia does not employ a single model of funding, but combines Bismarck's model (based on social insurance or payroll deductions) and Beveridge's model based on budget revenues (Croatian Health Insurance Fund, 2016).

In Croatia, the system of funding is predominantly public whereas the role of private health insurance is negligible. About 80% of the cost of health care is financed from compulsory contributions for health insurance. The remaining 20% of health care costs are covered from the state budget (general budget revenues), as well as from the supplementary and private health insurance. The funding of health services is performed by the Croatian Health Insurance Fund (hereinafter CHIF). It acts as an intermediary institution which collects contributions levied on income (health insurance contributions and other income) and distributes them to health care providers. The CHIF is a central financial institution of the health system. Until 2001, the funds for mandatory health insurance were raised from the direct payment of health insurance contributions to the accounts of CHIF. Starting with 2002, health insurance contributions were paid into the account of the State Treasury (the central state budget). However, in keeping with the legal regulation of the health care system, the contributions were earmarked as a source of financing for the health system. In 2015, the payment of contributions for health insurance was routed directly to the account of CHIF.

Hospitals are financed through monthly budget limits. Institutions should justify their claims by issuing invoices for the work that has been done. Agreements on the implementation of institutional health care contain the largest annual amount of funds for the provision of institutional health care that was agreed on, which results from the capacity of health institutions, the number of contracted beds and diagnostic and therapeutic procedures provided. In order to further define how hospitals are paid for the care they provide, it can be said that the service price is multiplied by the number of services performed, using an invoice that a medical institution issues for medical services provided and thus justifies the obtained funds. Hospital health care is paid on the basis of diagnostic and therapeutic groups (DRGs), days of care (DOC) for inpatient treatment, Census diagnostic and therapeutic procedures in the health sector (Blue Book) and by diagnostic and therapeutic procedures (DTP) for specialist health care (Croatian Health Insurance Fund, 2016). The funds credited for hospitals are strictly earmarked and used to cover the salaries of employees in health care and material costs of health care from the basic and supplementary health insurance. The development and investment in the health system are financed from sources other than the contracted funds of CHIF.

Table 1: The structure of total and due liabilities

Type of hospital	Total liabilities 31 Dec 2015, in millions HRK	Structure of total liabilities (%)	Total due liabilities 31 Dec 2015, in millions HRK	Structure of due liabilities (%)	Ratio of due and total liabilities
CHC, CH, C	2,626	64	1,301	65	0.50
General hospitals	1,355	33	674	34	0.50
Specialized hospitals	142	3	16	1	0.11
Total	4,124	100	1,991	100	0.48

Source: authors.

From the structure of total and due liabilities on December 31th, 2015 it is observed that Croatian public hospitals have liabilities that have not been paid on December 31th even if they were due to be paid. The ratio of due and total liabilities for CHC, CH and C and for General hospitals is 50%. The smallest due and total liabilities ratio value is in Specialized hospitals. Therefore, from Table 1 it can be concluded that Specialized hospitals are not generators of piled-up debt like the other two types of hospitals.

Other significant sources of funding for health care institutions are the state budget and the budgets of local and regional governments. The central government finances clinical hospitals and clinical hospital centres whereas counties finance general and specialized hospitals. The budget funds for financing health services are decentralized. Through the process of fiscal decentralization in 2001 the authority and resources dedicated to financing health care were transferred to local and regional governments (counties and cities). Decentralized funds are earmarked for capital investment in hospitals, medical equipment, and means of transport, for investment and ongoing maintenance of health facilities, computerization and the supply and maintenance of computer programs and computer equipment. The Law on the financing of local and regional governments (Official Gazette, 2012) defines the methods and sources of funds to cover the decentralized costs in the health system. With the goal of equal funding of all health institutions, the Croatian Government Decision establishes the minimum financial standards for decentralized functions for the current year (Official Gazette, 2015). Capital investments in the health system are financed through decentralized funds in the part intended for investment, as well as by additional funds of the Ministry of Health, by additional means of local and regional (regional) governments, EU funds, as well as by means of donations (companies, physical persons).

In addition to the aforementioned sources of funding, health institutions have income from other sources (their own sources): the generation of revenues under special regulations and doing business in the market. In other words, health institutions can generate revenues under special regulations concerning the payment of participation of service users to the full cost of services, payment protection of uninsured persons and foreigners, reimbursement of funds for services to foreign nationals, etc. Hospitals also perform certain tasks on the market and based on that generate revenues (revenues generated from renting space, service expertise, etc.).

Table 2: The structure of number of cases/patients and revenues

Type of hospital	Total number of cases/ patients in 2015	Structure of total cases/ patients (%)	Total revenues in 2015, (in millions HRK)	Structure of total revenues (%)	Average revenue in HRK per case/patient
CHC, CH, C	6,498,165	47	5,146	56	791
General hospitals	6,493,089	47	3,114	34	479
Specialized hospitals	791,610	6	883	10	1,111
Total	13,782,864	100	9,143	100	705

Source: authors.

Table 2 provides the total number of cases/patients. Since the total number of the cases/patients is almost 3 times higher than the total number of Croatian citizens, it can be concluded that some patients consume more health services. The average revenue per case/patient is the highest in Specialized hospitals and the lowest in General hospitals.

There are only 57 hospitals in Croatia and they could be used as an example of a small population. However, it has to be emphasized that hospitals are usually observed in order to survey patients about the quality of service and not to survey hospitals directly (CDC/National Center for Health Statistics, 2016). There are some cases when hospitals were surveyed directly, but in that case large samples were used (Herrin et al., 2015).

3. SIMPLE RANDOM SAMPLING, STRATIFIED RANDOM SAMPLING, AND TWO-STAGE CLUSTER SAMPLING

For the purpose of our research we used simple random sampling, stratified random sampling, and two-stage cluster sampling procedures. The basic characteristics and differences between these three procedures are discussed below. In simple random sampling, n sample units from total population or from N units, where $n<N$, are chosen at random. In the first step, each unit of the population is assigned a number from 1 to N. In the next step, in order to choose n units, a random process is used to construct the sample by using a table of random numbers, a computer, or a calculator with a random number generator (Levy, Lemeshow, 2008). In simple random sampling, each unit has the same probability to be chosen and which is equal to the ratio of sample size and population size (n/N). Furthermore, $\binom{N}{n}$ different samples of size n are possible when the population is of size N. In case of simple random sampling the estimate of mean is calculated as follows:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}, \tag{1}$$

where $\bar{x}$ is the unbiased estimate of the population mean or sample mean, x_i is the value of observed characteristic for *i*-th unit in the sample, *n* is the sample size or number of units in the sample.

In contrast to simple random sampling, the first step of stratified random sampling divides the population into non-overlapping, homogeneous groupings of population elements or strata (Heeringa, West, Berglund, 2010). In the next step, a certain number of units within each stratum are selected. A random sampling approach is usually employed to select a certain number of units within a stratum. In order to determine the number of units which are going to be selected within each stratum, probabilities proportional to size sampling is applied (Kish, 1995). In other words, if a stratum A has twice the population units than a stratum B, two times more units from the stratum A than from the stratum B are going to be sampled. In case of stratified random sampling, the estimated mean is calculated as follows:

$$\bar{x} = \frac{1}{N} \cdot \sum_{h=1}^{H} N_h \cdot \bar{x}_h \, , \tag{2}$$

where $\bar{x}$ is the unbiased estimate of the population mean or sample mean, *N* is the population size, N_h is the population size of stratum *h*, $\bar{x}_h$ is the sample mean of cluster *h*.

In cluster sampling, the population is also divided into non-overlapping, homogeneous groupings of population elements, but here the groups are called clusters. In contrast to stratified sampling, selected population units from each group are not selected in cluster sampling. So, in two-stage cluster sampling first groups or clusters are selected. In order to select clusters, random sampling or probabilities proportional to size approaches can be used (Kish, 1995). Consequently, in two-stage cluster sampling, in the first stage clusters are selected whereas in the second stage units from selected clusters are sampled. Therefore, the estimated mean at two-stage cluster sampling is equal to:

$$\bar{x} = \frac{A}{a \cdot N} \cdot \sum_{j=1}^{a} B_j \cdot \bar{x}_j \, , \tag{3}$$

where $\bar{x}$ is the unbiased estimate of the population mean or sample mean, *A* is the total number of clusters, *a* is the number of selected clusters in the first stage sampling, *N* is the population size, B_j is the total number of units in the *j*-th cluster, $\bar{x}_j$ is the sample mean of *j*-th cluster.

The equations (1)-(3) can be used to calculate the estimated mean at simple random sampling, stratified random sampling, and two-stage cluster sampling procedures. If a researcher is interested in the estimated total value, it can be easily obtained by multiplying the estimated mean and the population size.

4. DATA AND METHODS

The problem of sampling populations which are small in size is observed on the case of hospitals in Croatia. In 2015, there were 57 hospitals in Croatia. They are divided into three groups according to their specific characteristics: clinical hospital centres, clinical hospitals and clinics; general hospitals; and specialized hospitals. That classification will be used for complex survey design. For the purposes of stratified random sampling these groups are going to be treated as strata, whereas in two-stage cluster sampling they are going to have the role of clusters.

The variable of interest is the total due liabilities for medicines on December 31st, 2014 (which is the most recent period for which data were available in the time of writing the paper). This variable is chosen because it has a very important role in hospital budget planning, but also as it is important for state budget formation. It was highlighted above that hospitals are for the most part financed by the state. However, in order to estimate total due liabilities for medicines, the mean value will be estimated first. Consequently, more attention will be given to estimated mean calculations than to total calculations.

It has to emphasized that the total due liabilities for medicines for all hospitals on December 31st, 2014 are known and can be found in hospitals' statements. The simple random sampling, stratified random sampling, and two-stage cluster sampling procedures will be used in order to simulate the sampling procedure and enable comparisons between sampling means to the real population mean. This research design will enable us to provide answers to the given research questions and make conclusions about our research hypotheses. In the simulation, 9 different sample sizes for each observed sampling procedure are used. The sample sizes are defined as population shares. So, the first sample includes 10% of population units, the second sample includes 20% of population units, etc. Furthermore, it has been decided that at each sampling procedure and for each sample size the simulation will be conducted 10 times. Thus, the estimator's reliability is observed as well (Levy, Lemeshow, 2008). Consequently, for each sampling procedure 90 means and variances will be estimated. There are three observed sampling procedures, but at two-stage cluster sampling procedures will be made in order to distinguish between three situations. Namely, Hansen, Hurwitz and Madow (1953) have shown that the two-stage cluster sampling has a consistent variance if two or more clusters are selected and if sampling within a cluster does not depend on the sampling within other clusters. Because of that we observed only two clusters selections. Consequently, three situations will be inspected. In the first one it is assumed that the first and the second clusters are selected, in the second situation the first and the third clusters are selected, and in the third situation the second and the third cluster are selected.

In order to measure the accuracy of estimators at the observed three sampling procedures, the mean square error (MSE) approach is used. The accuracy of an estimator shows how far, on average, is a particular value of the mean estimate from the true value of the population mean (Levy, Lemeshow, 2008). The following equation presents the relation between the mean square error of a mean estimate to its bias and variance of sampling distribution:

$$MSE_{\bar{x}} = \sigma_{\bar{x}}^2 + B_{\bar{x}}^2, \tag{4}$$

where $MSE_{\bar{x}}$ is the mean square error of a mean estimate, $\sigma_{\bar{x}}^2$ is the variance of sampling distribution of mean parameter, $B_{\bar{x}}$ is the bias of a mean estimate.

Because of their special characteristics, for each sampling procedure the variance of sampling distribution of mean parameter is calculated in a different way. The variance of sampling mean distribution of mean parameter at simple random sampling is calculated as follows:

$$\sigma_{\bar{x}}^2(SRS) = \left(\frac{N-n}{N}\right)\cdot\left(\frac{s^2}{n}\right) = \left(\frac{N-n}{N}\right)\cdot\left(\frac{\sum_{i=1}^{n}(x_i-\bar{x})^2}{n\cdot(n-1)}\right), \tag{5}$$

where $\sigma_{\bar{x}}^2(SRS)$ is the variance of sampling mean distribution of mean parameter at simple random sampling, N is the population size, n is the sample size, s^2 is the estimate of the variance of the population mean, x_i is the value of observed characteristic of i-th unit in the sample, $\bar{x}$ is the sample mean.

When stratified random sampling procedure is applied, the variance of sampling mean distribution of mean parameter is calculated as follows:

$$\sigma_{\bar{x}}^2(STR) = \sum_{h=1}^{H}\left(\frac{N_h}{N}\right)^2\cdot\frac{s_h^2}{n_h}\cdot\left(\frac{N_h-n_h}{N_h}\right) = \sum_{h=1}^{H}\left(\frac{N_h}{N}\right)^2\cdot\left(\frac{\sum_{i=1}^{n_h}(x_{h,i}-\bar{x}_h)^2}{n_h\cdot(n_h-1)}\right)\cdot\left(\frac{N_h-n_h}{N_h}\right), \tag{6}$$

where $\sigma_{\bar{x}}^2(STR)$ is the variance of sampling mean distribution of mean parameter at stratified random sampling, H is the total number of strata, N_h is the population size of stratum h, N is the population size, s_h^2 is the estimate of the variance of the population mean of stratum h, n_h is the sample size of stratum h, $x_{h,i}$ is the value of observed characteristic of i-th unit in stratum h, $\bar{x}_h$ is the sample mean of cluster h.

In case of two-stage cluster procedure, the variance of sampling mean distribution of mean parameter is equal to:

$$\sigma_{\bar{x}}^2(CLU) = \left(\frac{A}{N}\right)^2\cdot\left(1-\frac{a}{A}\right)\cdot\frac{s_a^2}{a} + \frac{A}{N^2\cdot a}\cdot\sum_{j=1}^{a}\left[\left(1-\frac{b_j}{B_j}\right)\cdot B_j^2\cdot\frac{s_{b_j}^2}{b_j}\right], \tag{7}$$

where $\sigma_{\bar{x}}^2(CLU)$ is the variance of sampling mean distribution of mean parameter at two-stage cluster sampling, A is the total number of clusters, N is the population size, a is the number of selected clusters in the first stage sampling, s_a^2 is the sampling variance between clusters, b_j is the number of selected units from the j-th cluster in the second stage sampling, B_j is the total number of units in the j-th cluster, $s_{b_j}^2$ is the sampling variance within the j-th cluster. The sampling variance between clusters is calculated as follows:

$$s_a^2 = \frac{1}{a-1}\cdot\sum_{j=1}^{a}\left(B_j\cdot\bar{x}_j - \bar{B}_j\cdot\bar{x}\right)^2, \tag{8}$$

where s_a^2 is the sampling variance between clusters, a is the number of selected clusters in the first stage sampling, B_j is the total number of units in the j-th cluster, $\bar{x}_j$ is the sample mean of j-th cluster, $\bar{B}_j$ is the average number of units in the all j selected clusters, $\bar{x}$ is the unbiased estimate of the population mean or sample mean. The sampling variance within clusters is equal to:

$$s_{b_j}^2 = \frac{1}{b_j-1}\cdot\sum_{i=1}^{b_j}\left(x_i-\bar{x}_j\right)^2, \tag{9}$$

where $s_{b_j}^2$ is the sampling variance within the *j*-th cluster, b_j is the number of selected units from the *j*-th cluster in the second stage sampling, x_i is the value of observed characteristic for selected *i*-th unit in the *j*-th cluster, $\bar{x}_j$ is the sample mean of *j*-th cluster.

No matter which sampling procedure is used, the bias of a mean estimate is equal to:

$$B_{\bar{x}} = E_{\bar{x}} - \mu, \quad (10)$$

where $B_{\bar{x}}$ is the bias of an mean estimate, $E_{\bar{x}}$ is the expected value of the mean of the sampling distribution, μ is the population mean. For simple random sampling it has been shown that $E_{\bar{x}} = \mu$ (Halam, 2004). According to the Horvitz-Thompson estimator it has been assumed that a mean estimate is unbiased at stratified random sampling and two-stage cluster sampling procedures as well (Horvitz-Thompson, 1952, Barnett, 1981, Bethlehem, 2009). Accordingly, the bias of a mean estimate is omitted and the mean square error of a mean estimate is equal only to variance of sampling distribution of mean parameter.

5. RESULTS AND DISCUSSION

5.1. Descriptive statistics analysis

The analysis is conducted based on the data which are showing the total due liabilities for medicines in Croatian public hospitals on December 31st, 2014. The basic descriptive statistics results are provided in Table 3.

Table 3: Basic descriptive results of the total due liabilities for medicines in Croatian public hospitals on December 31st, 2014, values in millions of Croatian kunas

Statistics	Overall	Strata		
		Clinical hospital centres, hospital centres and clinics	General hospitals	Specialized hospitals
Population size	57	10	21	26
Mean	13.54	53.00	10.59	0.74
Mode	0	---	---	0
Variance	892	2,914	72	6
Standard deviation	30	54	8	2
Coefficient of variation	221	102	80	322
Minimum	0	0	1	0
1st Quartile	0	20	4	0
Median	3	39	7	0
3rd Quartile	12	56	14	0
Maximum	197	197	30	12
Range	197	197	29	12
Interquartile range	12	36	10	0
Number of outliers	1	0	0	1

Source: authors' calculations.

According to Table 3 results, the average total due liabilities for medicines in all 57 Croatian public hospitals on December 31st, 2014 were 13.54 million of Croatian kunas. However, 14 hospitals had no total due liabilities for medicines on the observed date. Furthermore, 75% of hospitals had total due liabilities for medicines equal to or lower than 12 million Croatian kunas, whereas 25% of hospitals had total due liabilities for medicines equal to or higher than 12 million Croatian kunas. On the other hand, the highest total due liabilities for medicines was 197 million of Croatian kunas. Consequently, the data variation level can be considered as very high, which is confirmed by the coefficient of variation of 221%.

The conducted outlier analysis has detected the presence of an outlier. As an outlier, we consider a data point which deviates by more than three standard deviations from the mean value. The outlier here is the hospital which had the highest total due liabilities for medicines: 197 million of Croatian kunas. However, it is thought that the differences in observed sampling procedures are going to be more pronounced if the observed variable has a high variability level. Because of that, this outlier was not omitted from the further analysis.

In Table 3, basic descriptive statistics results for hospital strata are also provided. As was expected, total due liabilities for medicines are, on average, the highest in large hospitals, e.g. Clinical hospital centres, hospital centres and clinics. On the opposite side, Specialized hospitals have the lowest average total due liabilities for medicines. However, in all three strata data variability level is high. It can be concluded that hospitals within each stratum separately are not very homogeneous. An evident outlier is present only among Specialized hospitals whereas the other two strata seem not to have outliers.

5.2. Simple random sampling analysis

In simple random sampling units are selected completely randomly from the population. Consequently, hospitals for samples were chosen randomly, taking into account all 57 hospitals and by using a random number generator. For each of the 9 different sample sizes, 10 samples of hospitals were chosen separately. So, 90 random selections of hospitals were conducted. At each selection each hospital had the same initial probability to be chosen into the sample and which was equal to 1/57 or 0.0175. The mean total due liabilities for medicines in Croatian public hospitals on December 31st, 2014 of hospitals in samples and standard errors at simple random sampling are given in Table 4. The sample mean values are calculated by using equation (1) whereas standard errors were calculated as root squares of variances of sampling mean distribution of mean parameter which are defined by equation (5).

Table 4: Sample means and standard errors of the total due liabilities for medicines in Croatian public hospitals on December 31st, 2014, simple random sampling procedure, values in millions of Croatian kunas

No. of sample	Statistics	Sample size								
		6	12	18	23	29	35	40	46	52
1	Average	8.89	23.45	9.35	14.55	9.01	17.01	15.21	11.19	13.45
	Std. Error	6.46	14.14	2.69	6.55	1.60	3.85	2.87	1.21	1.28
2	Average	9.35	13.56	15.17	7.97	5.83	14.77	12.02	12.39	13.01
	Std. Error	6.41	6.66	8.97	2.09	1.41	3.88	2.77	2.02	1.26
3	Average	34.42	16.04	15.60	16.27	6.86	11.19	11.67	15.17	13.52
	Std. Error	11.87	7.04	4.87	7.08	1.50	2.04	1.67	2.14	1.28
4	Average	2.12	23.63	7.00	14.54	10.44	15.61	14.40	14.17	14.12
	Std. Error	1.16	14.31	2.88	3.84	2.54	3.89	2.97	2.01	1.29
5	Average	8.38	10.33	12.58	16.68	16.80	14.38	15.49	12.75	14.15
	Std. Error	4.38	6.58	4.42	3.80	4.86	3.66	3.04	2.01	1.28
6	Average	10.10	33.10	7.94	8.52	17.88	12.80	13.43	14.79	13.73
	Std. Error	7.86	14.96	2.40	2.21	5.20	3.56	2.99	2.14	1.26
7	Average	41.06	11.18	15.19	11.48	10.09	13.41	8.01	14.76	14.34
	Std. Error	30.13	4.12	4.50	3.26	2.63	2.15	0.97	2.11	1.29
8	Average	14.60	30.27	9.53	11.39	18.32	17.19	10.10	12.12	13.02
	Std. Error	9.32	14.88	2.40	3.24	5.23	3.93	1.58	1.99	1.21
9	Average	5.21	18.87	8.47	21.79	8.61	17.33	13.30	15.62	14.45
	Std. Error	2.08	5.39	2.59	6.80	1.92	3.83	2.79	2.14	1.29
10	Average	15.36	4.64	6.76	12.54	16.03	12.53	6.26	8.77	13.31
	Std. Error	14.26	2.47	2.01	2.77	5.12	1.99	0.79	1.09	1.28
Samples averages	Average	14.95	18.51	10.76	13.57	11.99	14.62	11.99	13.17	13.71
	Std. Error	9.39	9.06	3.77	4.16	3.20	3.28	2.24	1.89	1.27

Source: authors' calculations.

As expected, there was no sample at which sample mean was equal to population mean. However, according to the results from Table 4, the sample mean was the nearest to the population mean in the third sample, when sample size was 52 hospitals (sample mean = 13.52, standard error = 1.28). On the other hand, the highest difference from the population mean was achieved at the seventh sample, when sample size was 6 hospitals (sample mean = 41.06, standard error = 30.13).

These results are suggesting that the higher sample size is, the more precise the sample estimate of the observed variable is (here the average total due liabilities for medicines in Croatian public hospitals on December 31st, 2014). Actually, the estimate came very close to the population real value. In order to inspect this statement, the averages across all 10 samples for each of 9 different sample sizes were calculated. According to the results in Table 4, the average of sample averages, when the sample size was 23 hospitals, was 13.57 million Croatian kunas, what was the nearest to the population mean value. The worst average estimation of total due liabilities for medicines in Croatian public hospitals on December 31st, 2014 was achieved when samples of 12 hospitals were observed.

Due to the aforementioned, it can be concluded that the precision of the average value across all 10 samples together does not depend on the sample size. However, it has been shown that the higher sample size is, the more likely it is that the sample estimate precision will be higher. In case of samples including 52 hospitals, all 10 sample means are within the error margin of 1 million Croatian kuna from the population mean. Consequently, the average standard error across all 10 samples is the lowest here. On the other hand, only one sample mean, when samples of 23 hospitals are observed, is within the error margin of 1 million Croatian kuna from the population mean. Still, on average across all 10 samples, samples of 23 hospitals gave the most precise average in comparison to other sample sizes. Despite that, the average standard error across all 10 samples of size 23 was more than three times higher than the average standard error across all 10 samples of size 52.

5.3. Stratified random sampling analysis

In order to perform stratified random sampling analysis, three strata of hospitals are defined. The first stratum consisted of *Clinical hospital centres, hospital centres and clinics*, the second one of *General hospitals*, and the third stratum includes *Specialized hospitals*. Because all three strata are of different sizes, the number of hospitals, which will be randomly chosen from each stratum, is determined proportional to the sample size. In Table 5, the number of selected hospitals from each stratum for different sample sizes is shown.

Table 5: Number of selected hospitals from each stratum for different sample sizes, proportionate allocation

Stratum	Sample size								
	6	**12**	**18**	**23**	**29**	**35**	**40**	**46**	**52**
Clinical hospital centres, hospital centres and clinics	1	2	3	4	5	6	7	8	9
General hospitals	2	4	7	8	11	13	15	17	19
Specialized hospitals	3	6	8	11	13	16	18	21	24

Source: authors' calculations.

According to the distribution of hospitals presented in Table 5 for each sample size, 10 random selections were conducted and sample means and standard errors of the total due liabilities for medicines in Croatian public hospitals on December 31st, 2014 were calculated. The sample means were calculated using equation (2) whereas the standard errors were calculated by calculating the square root from the value which was the result of equation (6). The sample means and the standard errors calculated by using the stratified random sampling procedure are given in Table 6.

Table 6: Sample means and standard errors of the total due liabilities for medicines in Croatian public hospitals on December 31st, 2014, stratified random sampling procedure, values in millions of Croatian kunas

No. of sample	Statistics	Sample size								
		6	12	18	23	29	35	40	46	52
1	Average	24.08	10.96	11.11	18.68	7.93	13.83	14.65	13.77	13.63
	Std. Error	1.32	4.26	2.37	5.32	1.28	3.27	2.48	1.81	1.14
2	Average	8.13	13.22	9.85	13.02	14.72	16.54	13.95	10.38	14.67
	Std. Error	0.45	2.19	2.69	1.13	4.48	3.10	2.42	0.88	1.10
3	Average	7.46	9.95	9.81	15.73	20.36	17.82	10.85	11.68	13.49
	Std. Error	0.19	1.44	2.85	6.15	3.61	2.86	1.15	0.80	1.14
4	Average	10.26	28.89	13.74	17.00	9.79	9.60	14.53	14.83	14.14
	Std. Error	0.25	8.47	2.81	6.01	1.56	1.15	2.35	1.78	1.13
5	Average	2.63	16.87	11.74	13.47	13.98	15.78	14.57	13.05	14.42
	Std. Error	0.72	3.38	2.07	1.82	4.34	3.30	2.56	1.78	1.08
6	Average	11.77	10.13	11.03	17.38	9.51	14.93	16.68	10.89	13.35
	Std. Error	2.84	3.21	4.42	6.00	2.04	3.19	2.30	0.83	1.13
7	Average	18.11	7.50	15.02	8.24	14.89	14.32	14.92	13.90	12.94
	Std. Error	0.40	3.27	2.87	3.00	4.39	3.38	2.45	1.80	1.11
8	Average	11.62	12.20	16.73	13.15	18.57	7.62	9.34	9.96	14.06
	Std. Error	0.15	3.59	8.69	2.37	4.13	0.96	0.94	0.87	1.14
9	Average	42.46	7.14	13.59	12.46	10.67	14.82	10.94	14.32	12.81
	Std. Error	5.19	1.93	2.96	2.62	1.90	3.10	1.08	1.81	1.11
10	Average	37.49	12.78	15.53	17.80	11.19	17.06	9.46	15.30	13.73
	Std. Error	0.56	1.13	9.30	6.18	2.04	3.13	0.88	1.74	1.14
Samples averages	Average	17.40	12.96	12.81	14.69	13.16	14.23	12.99	12.81	13.72
	Std. Error	1.21	3.29	4.10	4.06	2.98	2.74	1.86	1.41	1.12

Source: authors' calculations.

In Table 6 the mean values of sample means and standard errors across samples of the same size are provided as well. As expected, samples of size of 52 hospitals (the largest samples) were on average the closest to the real population mean of the total due liabilities for medicines in Croatian public hospitals on December 31st, 2014 whereas samples of 6 hospitals (the smallest samples) were in average the farthest from the population mean. However, increasing the sample size did not necessarily improve the precision of the estimate. For example, samples of size of 12 hospitals were on average closer to the population mean than samples of size of 46 hospitals. Still, it can be noticed that with increase of the sample size the average standard errors generally decreased. The sample of sizes 6 and 12 are exceptions to this rule. The explanation for that should be found in the contents of the strata. Namely, the third stratum with *Specialized hospitals* has the largest share in the samples because, in comparison to the other two strata, it includes the majority of hospitals. The problem is that the hospitals in *Specialized hospitals* strata have significantly lower total due liabilities for medicines in Croatian public hospitals on December 31st, 2014 when compared to the hospitals from the other two strata, which fact has a significant impact on the standard errors value. Furthermore, in the sample of size of 6 hospitals only one hospital from the *Clinical hospital centres, hospital centres and clinics* stratum was chosen. Consequently, it was impossible to calculate the variance of this stratum. As a result, it was assumed that the variance of the first stratum at sample size of 6 hospitals is equal to zero. That had impact on the standard errors values as well.

5.4. Two-stage cluster sampling analysis

In two-stage cluster sampling, at the first stage clusters are randomly selected, and at the second stage units within selected clusters are randomly selected. Three groups of hospitals could be recognized: *Clinical hospital centres, hospital centres and clinics; General hospitals and Specialized hospitals.* As mentioned before, it is assumed that from these three groups/clusters two are chosen. Consequently, three different cases of clusters selection will be observed. In the first case, clusters *Clinical hospital centres, hospital centres and clinics* and *General hospitals* are selected, in the second case we observe *Clinical hospital centres, hospital centres and clinics* and *Specialized hospitals*, and in the third case *General hospitals* and *Specialized hospitals* clusters are selected. In order to maintain the comparability with the two sampling procedures used previously, the same sample sizes as before are considered. The number of selected hospitals within each selected cluster is determined by using proportionate to size allocation. The number of selected hospitals from each selected cluster for different sample sizes is given in Table 7.

Table 7: Number of selected hospitals from each selected cluster for different sample sizes, proportionate allocation

Clusters	Sample size								
	6	12	18	23	29	35	40	46	52
Case 1:									
Clinical hospital centres, hospital centres and clinics	2	4	6	7	9	-	-	-	-
General hospitals	4	8	12	16	20	-	-	-	-
Case 2:									
Clinical hospital centres, hospital centres and clinics	2	3	5	6	8	-	-	-	-
Specialized hospitals	4	9	13	17	21	-	-	-	-
Case 3:									
General hospitals	3	5	8	10	13	16	18	-	-
Specialized hospitals	3	7	10	13	16	19	22	-	-

Source: authors' calculations.

The data from Table 7 show that at two-stage cluster sampling the sample sizes are more restricted than in the other two observed sampling procedures. In other words, at two-stage cluster sampling a part of the population, which can be found in clusters which have not been selected, is omitted on purpose. Consequently, sample sizes cannot be as large as they can be at simple random sampling or at stratified random sampling procedures. So, the sample sizes are restricted primarily by the population sizes of selected clusters. Therefore, the largest possible sample sizes at Case 1 and Case 2 are 29 hospitals whereas at Case 3 the largest sample which can be made comprises 40 hospitals.

According to the distribution of hospitals given in Table 7, 10 random selections of hospitals were conducted for each sample size. After the selection, equation (3) was used to calculate sample means of the total due liabilities for medicines in Croatian public hospitals on December 31st, 2014, while standard errors were calculated by taking square roots from the results provided by using equation (7). That procedure was repeated for all three cases and the corresponding results are given in Tables 8, 9 and 10.

Table 8: Sample means and standard errors of the total due liabilities for medicines in Croatian public hospitals on December 31st, 2014, two-stage cluster sampling, Case 1 – selected *Clinical hospital centres, hospital centres and clinics* and *General hospitals* clusters, values in millions of Croatian kunas

No. of sample	**Statistics**	**Sample size**								
		6	**12**	**18**	**23**	**29**	**35**	**40**	**46**	**52**
1	Average	12.20	11.22	6.70	10.08	15.32	---	---	---	---
	Std. Error	4.56	5.41	2.57	3.53	5.92	---	---	---	---
2	Average	16.48	8.17	10.35	14.02	13.53	---	---	---	---
	Std. Error	10.31	4.77	4.08	6.12	5.52	---	---	---	---
3	Average	15.03	8.51	16.22	8.52	13.13	---	---	---	---
	Std. Error	10.55	4.80	7.48	2.91	6.12	---	---	---	---
4	Average	19.67	6.54	9.40	10.63	8.30	---	---	---	---
	Std. Error	9.80	3.53	3.59	4.07	3.23	---	---	---	---
5	Average	15.06	5.89	9.08	6.47	12.35	---	---	---	---
	Std. Error	4.04	3.01	3.90	2.66	6.24	---	---	---	---
6	Average	21.56	9.98	8.00	6.69	8.91	---	---	---	---
	Std. Error	9.09	5.70	3.22	1.71	2.42	---	---	---	---
7	Average	30.83	16.24	7.61	11.10	15.04	---	---	---	---
	Std. Error	22.87	10.40	2.34	4.41	5.75	---	---	---	---
8	Average	30.82	9.81	6.11	6.28	9.42	---	---	---	---
	Std. Error	23.55	4.51	2.20	2.77	2.32	---	---	---	---
9	Average	10.34	19.72	7.86	18.22	13.45	---	---	---	---
	Std. Error	5.96	11.59	2.97	7.45	5.45	---	---	---	---
10	Average	28.55	10.77	11.31	8.37	9.03	---	---	---	---
	Std. Error	23.41	3.25	4.12	3.41	3.06	---	---	---	---
Samples averages	Average	20.06	10.68	9.27	10.04	11.85	---	---	---	---
	Std. Error	12.41	5.70	3.65	3.90	4.60	---	---	---	---

Source: authors' calculations.

Table 9: Sample means and standard errors of the total due liabilities for medicines in Croatian public hospitals on December 31st, 2014, two-stage cluster sampling, Case 2 – selected *Clinical hospital centres, hospital centres and clinics* and *Specialized hospitals* clusters, values in millions of Croatian kunas

No. of sample	Statistics	Sample size								
		6	12	18	23	29	35	40	46	52
1	Average	7.54	21.17	12.06	10.97	17.45	---	---	---	---
	Std. Error	6.99	15.58	7.02	5.85	9.50	---	---	---	---
2	Average	19.46	9.28	9.81	18.39	14.98	---	---	---	---
	Std. Error	11.70	5.08	5.74	10.64	8.09	---	---	---	---
3	Average	5.57	8.27	22.16	17.52	13.86	---	---	---	---
	Std. Error	3.87	5.10	12.65	10.68	7.40	---	---	---	---
4	Average	3.18	9.37	8.74	15.51	15.83	---	---	---	---
	Std. Error	1.85	5.75	4.31	9.15	8.57	---	---	---	---
5	Average	5.83	8.97	20.09	15.42	10.33	---	---	---	---
	Std. Error	3.76	5.01	11.80	9.52	5.45	---	---	---	---
6	Average	9.41	7.77	13.00	12.34	15.69	---	---	---	---
	Std. Error	5.85	4.00	6.91	6.55	8.88	---	---	---	---
7	Average	12.18	9.04	16.13	15.12	15.52	---	---	---	---
	Std. Error	11.03	5.79	9.81	9.36	8.41	---	---	---	---
8	Average	8.91	8.75	17.62	6.74	14.96	---	---	---	---
	Std. Error	5.15	4.60	11.35	3.91	8.46	---	---	---	---
9	Average	8.74	7.42	13.79	7.85	16.48	---	---	---	---
	Std. Error	3.57	4.59	7.91	4.53	9.68	---	---	---	---
10	Average	5.41	26.32	10.72	16.32	16.11	---	---	---	---
	Std. Error	3.94	16.76	6.40	9.48	8.62	---	---	---	---
Samples averages	Average	8.62	11.64	14.41	13.62	15.12	---	---	---	---
	Std. Error	5.77	7.22	8.39	7.97	8.30	---	---	---	---

Source: authors' calculations.

Table 10: Sample means and standard errors of the total due liabilities for medicines in Croatian public hospitals on December 31st, 2014, two-stage cluster sampling, Case 3 – selected *General hospitals* and *Specialized hospitals* clusters, values in millions of Croatian kunas

No. of sample	Statistics	Sample size								
		6	12	18	23	29	35	40	46	52
1	Average	12.29	7.12	7.05	6.36	7.41	7.14	5.59	---	---
	Std. Error	7.10	3.43	3.11	2.89	4.29	3.60	2.71	---	---
2	Average	2.26	8.95	3.78	4.92	7.30	6.97	6.51	---	---
	Std. Error	1.46	4.41	2.30	2.85	3.55	3.55	3.27	---	---
3	Average	6.51	4.01	5.23	5.08	6.18	6.17	6.49	---	---
	Std. Error	2.63	2.32	3.02	2.29	3.57	3.42	3.25	---	---
4	Average	2.68	4.94	7.83	6.27	6.32	6.52	6.55	---	---
	Std. Error	1.73	2.96	4.56	3.54	2.93	3.14	3.28	---	---
5	Average	6.67	7.78	9.30	5.70	5.17	7.40	6.42	---	---
	Std. Error	2.66	3.37	4.50	3.24	2.29	3.66	3.59	---	---
6	Average	4.06	4.60	6.78	6.34	6.10	6.63	6.44	---	---
	Std. Error	1.26	3.06	3.80	3.71	2.95	3.26	3.26	---	---
7	Average	6.62	6.04	5.62	7.15	6.87	5.30	6.65	---	---
	Std. Error	4.70	3.65	3.34	3.43	3.33	2.49	3.35	---	---
8	Average	8.93	6.61	7.31	5.37	6.42	6.93	6.66	---	---
	Std. Error	3.79	4.08	4.31	3.05	3.07	3.43	3.31	---	---
9	Average	6.39	6.58	6.84	5.20	6.18	7.50	6.69	---	---
	Std. Error	4.39	4.21	2.89	2.85	2.99	3.77	3.33	---	---
10	Average	7.73	7.78	6.47	4.76	5.78	6.61	6.19	---	---
	Std. Error	4.99	5.09	3.67	2.65	2.79	3.74	3.03	---	---
Samples averages	Average	6.41	6.44	6.62	5.71	6.37	6.72	6.42	---	---
	Std. Error	3.47	3.66	3.55	3.05	3.17	3.41	3.24	---	---

Source: authors' calculations.

When using cluster sampling procedure, some parts of populations are omitted deliberately. The possible consequences of that are visible if we consider Case 3, where *General hospitals* and *Specialized hospitals* clusters are selected. According to Table 10, all samples had a lower average value of total due liabilities for medicines in Croatian public hospitals on December 31st, 2014 than the population average. This can be explained by the fact that the hospitals in the omitted *Clinical hospital centres, hospital centres and clinics* cluster have a significantly higher population average value of the total due liabilities for medicines in Croatian public hospitals on December 31st, 2014 when compared to the population average of hospitals in other two clusters. Therefore, the average value of the total due liabilities for medicines in Croatian public hospitals on December 31st, 2014 at Case 3 is always underestimated.

5.5. Results comparison and discussion

The conducted analysis has shown that different sampling procedures resulted in different accuracy and precision levels of estimate. Here the estimate of average total due liabilities for medicines in Croatian public hospitals on December 31st, 2014 is observed. Generally speaking, it is thought that the sample size has an important role in reaching the desired level of precision and accuracy (Naing, Winn, Rusli, 2006, Brown, 2007). In order to investigate if that is the case in our case, different sample sizes are observed. For each observed sample size 10 samples are formed and theirs average and standard errors values are calculated. In order to decrease the impact of selecting a "very bad" or "very good" sample[1], in the further analysis the average of averages and the average of standard errors of those are used to compare the results of the three observed sampling procedures.

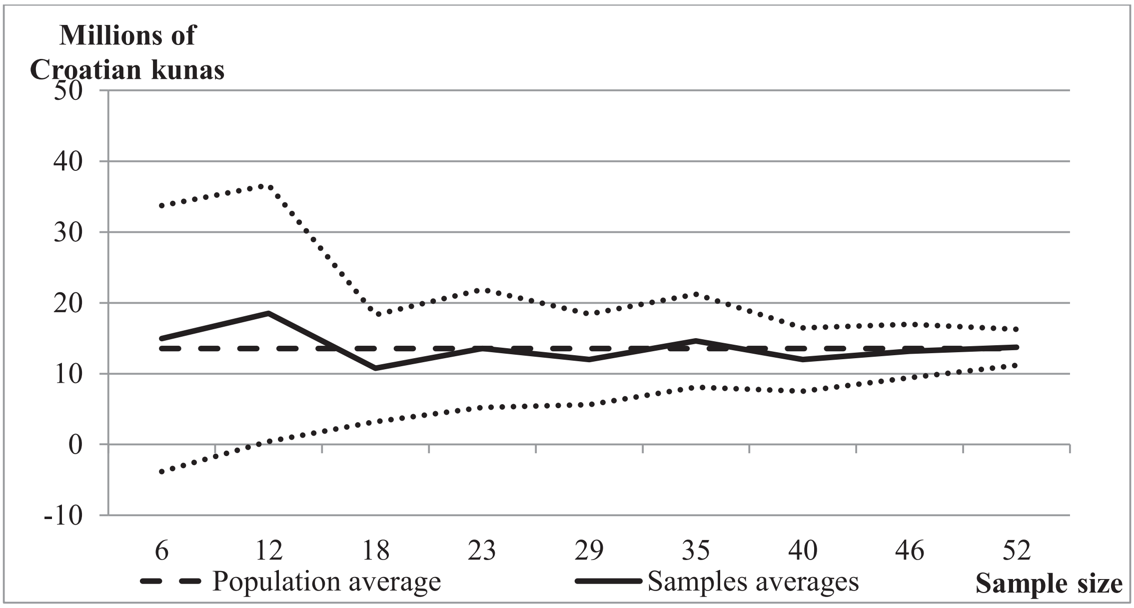

Figure 1: Population average of total due liabilities for medicines in Croatian public hospitals on December 31st, 2014 and averages of sample averages with confidence intervals, simple random sampling procedure, values in millions of Croatian kunas

Note: Doted lines are showing interval of +/- 2 standard errors from the sample average.

Source: authors' calculations.

In Figure 1, samples averages and their confidence intervals, which represent a deviation of +/- 2 standard errors from the sample average, calculated at simple random sampling procedure are shown. For easier comparison of achieved precision and accuracy levels, the population average is also given in Figure 1. It has to be emphasized that no matter what

[1] Here under "very bad" samples are considered those samples which are consisted from hospitals which total due liabilities for medicines on December 31st, 2014 are significantly different from the average one (average is the observed parameter). On the other hand, "very good" samples are those samples which consisted of hospitals whose total due liabilities for medicines on December 31st, 2014 are very close to the average one.

sample size is observed, the population average is always the same. Because of that, population average is presented by a straight line in Figure 1.

Figure 1 reveals that, at simple random sampling procedure, no matter which sample size is observed, on average, samples averages are quite near to the population average. However, confidence intervals at sample sizes 6 and 12 are quite wider than at larger samples. The narrowest confidence interval is achieved when the largest sample of 52 public hospitals is observed. The confidence intervals at sample sizes of 40 and 46 could be also observed as to be quite narrow. Consequently, it can be concluded that selecting at least 70% of population units in the sample, here selecting at least 40 public hospitals, by using simple random sampling procedure, would in average lead to a narrow confidence interval.

The confidence interval incorporates the uncertainty bound up with the average estimate. Also, it represents a range of values within which it can be reasonably certain that the population average actually lies. The wider the confidence interval is, greater the uncertainty is. Intervals that are very wide indicate that there is a lack of knowledge and information, it means that the researchers did not have enough data (Schünemann et al., 2011). Accordingly, it can be concluded that using at least 70% of units of a small population and applying the simple random sampling procedure will on average provide enough knowledge and information, leading to a narrow confidence interval. In other words, 70% of units will provide enough data to reach a satisfactory level of knowledge and information for the purpose of average estimate. So, if we use the simple random sampling procedure in small populations in order to calculate the average variable, at least 70% of units need to be sampled to reach a quality base for making a precise and accurate average estimate. In contrast, samples which have less than 30% small population units, here samples with fewer than 18 public hospitals, on average cannot ensure even close enough knowledge and information level for a precise and accurate average estimate.

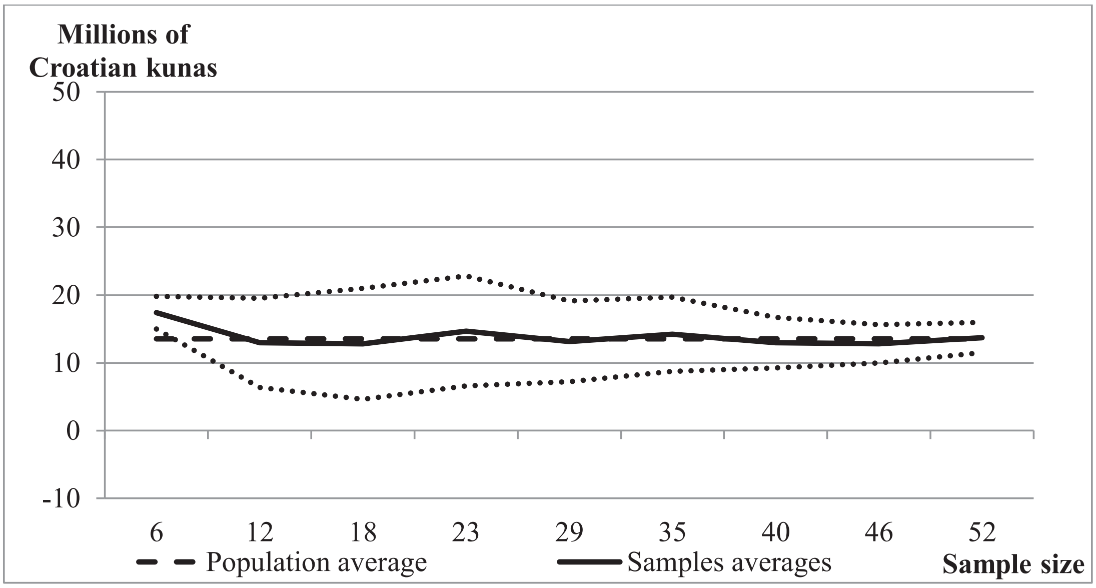

Figure 2: Population average of total due liabilities for medicines in Croatian public hospitals on December 31st, 2014 and averages of sample averages with confidence intervals, stratified random sampling procedure, values in millions of Croatian kunas

Note: Doted lines are showing interval of +/- 2 standard errors from the sample average.

Source: authors' calculations.

In Figure 2, samples averages and their confidence intervals calculated by using the stratified random sampling procedure are shown. For easier comparison of different sampling procedures, the elements and measures in Figure 2 are the same as in Figure 1.

In contrast to the simple random sampling procedure, the stratified random sampling procedure has on average resulted in narrower confidence intervals at almost all sample sizes (exception is sample of size 18 public hospitals). Furthermore, the line of samples averages is, in general, much closer to the real population average. However, this is a result of taking averages across 10 samples of the same size. In reality, after taking a closer look at the data, it can be concluded that some sample averages are considerably far from the population mean. The differences between samples averages become acceptably small after the sample size of 29 public hospitals. Therefore, it can be concluded that it is not recommendable to sample less than 50% of overall population units when using the stratified random sampling procedure. On the other hand, very narrow confidence intervals and acceptable variation levels between samples averages are recorded starting from sample size of 40 public hospitals. Consequently, it can be concluded that by using the stratified random sampling procedure at least 70% of total population units must be sampled in order to get enough knowledge and information for a precise and accurate average estimate.

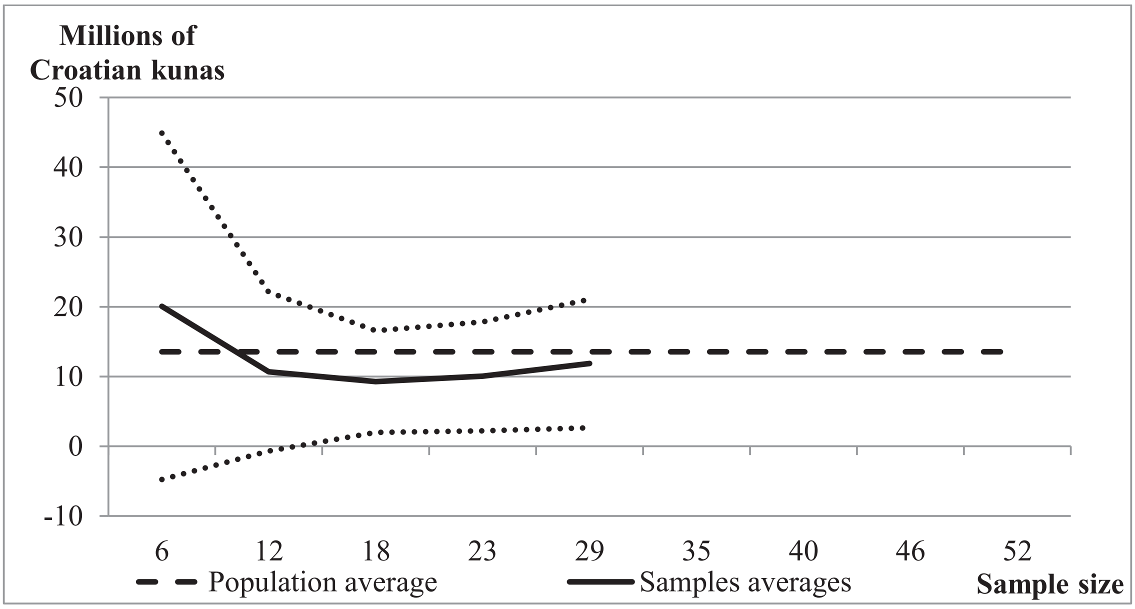

Figure 3: Population average of total due liabilities for medicines in Croatian public hospitals on December 31st, 2014 and averages of sample averages with confidence intervals, two-stage cluster sampling, Case 1 – selected *Clinical hospital centres, hospital centres and clinics* and *General hospitals* clusters, values in millions of Croatian kunas

Note: Doted lines are showing interval of +/- 2 standard errors from the sample average.

Source: authors' calculations.

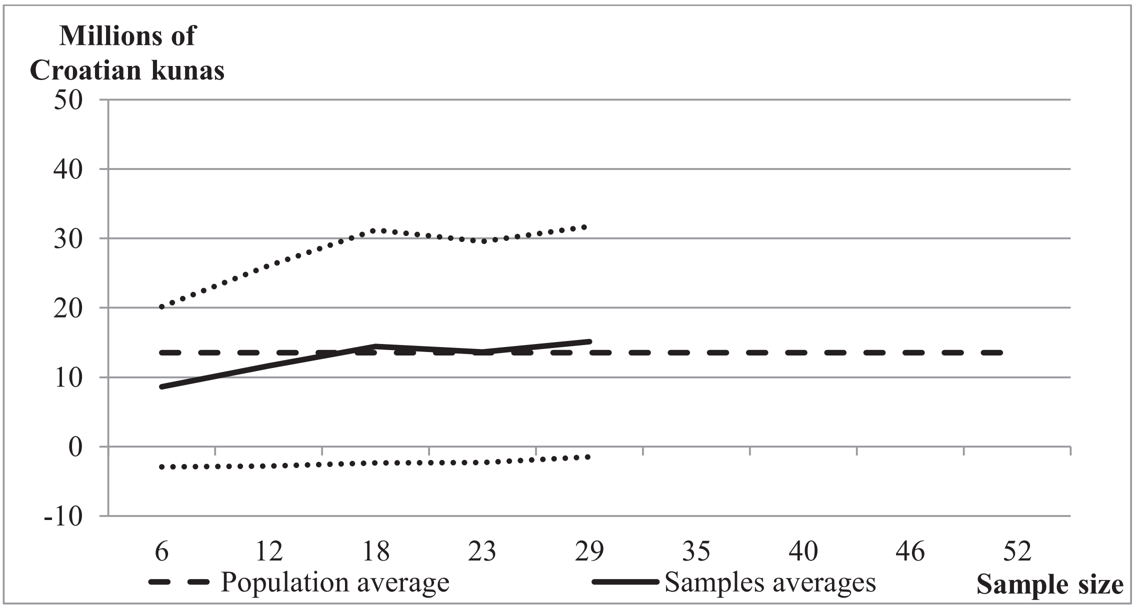

Figure 4: Population average of total due liabilities for medicines in Croatian public hospitals on December 31st, 2014 and averages of sample averages with confidence intervals, two-stage cluster sampling, Case 2 – selected *Clinical hospital centres, hospital centres and clinics* and *Specialized hospitals* clusters, values in millions of Croatian kunas

Note: Doted lines are showing interval of +/- 2 standard errors from the sample average.

Source: authors' calculations.

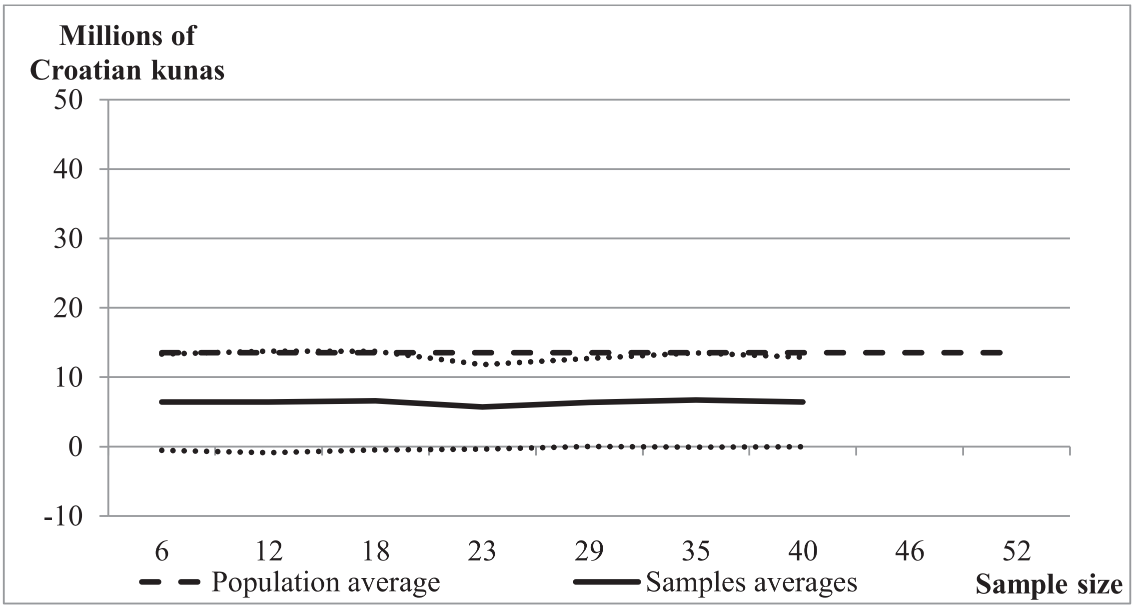

Figure 5: Population average of total due liabilities for medicines in Croatian public hospitals on December 31st, 2014 and averages of sample averages with confidence intervals, two-stage cluster sampling, Case 3 – selected *General hospitals* and *Specialized hospitals* clusters, values in millions of Croatian kunas

Note: Doted lines are showing interval of +/- 2 standard errors from the sample average.

Source: authors' calculations.

In Figure 3, Figure 4 and Figure 5 samples averages and their confidence intervals for two-stage cluster sampling are shown. In Figure 3 Case 1 is observed (when *Clinical hospital centres, hospital centres* and *clinics* and *General hospitals* clusters are selected). In Figure 4 Case 2 is observed (when *Clinical hospital centres, hospital centres and clinics* and *Specialized hospitals* clusters are selected). In Figure 5 Case 3 is observed (*General hospitals* and *Specialized hospitals* clusters are selected). Since all three cases use the same sampling procedure, all three figures are going to be used together in order to make conclusions about the minimal and recommended sampling rate at two-stage cluster sampling.

At cluster sampling, some population units are on purpose omitted from the sampling process. Consequently, two-stage cluster sampling is in start restricted with the maximum sample size. The larger the cluster which was omitted is, the smaller the sample size can be. Here three clusters are recognized. When the *General hospitals* or the *Specialized hospitals* cluster were omitted, the maximum sample size consisted of 50% of population units whereas the omission of *Clinical hospital centres, hospital centres* cluster resulted in the maximum sample size of 70% population units.

Figure 3 and Figure 4 suggest that at two-stage cluster sampling procedure it is not recommended to sample less than 50% of overall population units. However, Figure 5 shows that even when 70% of overall population units are sampled, they do not provide enough knowledge and information for precise and accuracy average estimate. According to Figure 5, there are no real differences in averages and confidence intervals when samples of different sizes are observed. In other words, larger sample sizes at two-stage cluster sampling are required. Still, the increase of sample size is not possible because of two-stage cluster sampling characteristics. Consequently, it can be concluded that two-stage cluster sampling procedure is not applicable when small populations are observed and investigated.

Table 11: Recommended and minimum allowed overall sampling rates for small populations by using different sampling procedures

Sampling procedure	Minimum recommended overall sampling rate	Minimum allowed overall sampling rate
Simple random sampling	70%	30%
Stratified random sampling	70%	50%
Two-stage cluster sampling	N/A	N/A

Source: authors' calculations.

The summarized conclusions about the minimum recommended and minimum allowed overall sampling rates are presented in Table 11. According to Table 11, in case of small populations, the best solution would be to use the simple random sampling procedure and to sample at least 70% of population units. In certain cases the sampling rate could be set lower but under no circumstances under 30% of population units. On the other hand, the two-stage cluster sampling procedure proved to be useless when the observed population is small. This is so because the two-stage cluster sampling procedure reduces the population available for sampling by omitting clusters of units right in the beginning. As a result, a small population is made to be even smaller. Finally, the first research hypothesis can be accepted only partially. Namely, in order to get a satisfactory precision and accuracy levels of parameter estimates, at least 50% of population units should be sampled at the simple random sampling and at the stratified random sampling procedures. On the other hand, the two-stage cluster sampling procedure cannot ensure satisfactory precision and accuracy levels of parameter estimates at any inspected sampling rate.

It is expected that the stratified random sampling procedure, because of its sampling characteristics, would result in more accurate results when compared to the simple random sampling and two-stage cluster sampling results at the same sample sizes. In order to investigate that statement, the averages of observed parameter for each sample size at each observed sampling procedure were calculated and compared to the population parameter value. The absolute values of differences between the estimated and population average are given in Table 12.

Table 12: Absolute differences between estimated and population average of the total due liabilities for medicines in Croatian public hospitals on December 31st, 2014, for the observed sample sizes at the observed sampling procedures, values in millions of Croatian kunas

Sampling procedure	Sample size								
	6	12	18	23	29	35	40	46	52
Simple random sampling	1.41	4.97	2.78	0.04	1.55	1.09	1.55	0.36	0.18
Stratified random sampling	3.87	0.57	0.72	1.16	0.37	0.70	0.55	0.73	0.19
Two-stage cluster sampling - Case 1	6.52	2.85	4.27	3.50	1.69	---	---	---	---
Two-stage cluster sampling - Case 2	4.91	1.90	0.88	0.08	1.59	---	---	---	---
Two-stage cluster sampling - Case 3	7.12	7.09	6.91	7.82	7.16	6.82	7.11	---	---

Source: authors' calculations.

According to the results provided in Table 12, there is no dominant sampling procedure which would result in the smallest difference between the estimated and population average for all observed procedures. So, the higher accuracy level is not determined by choosing a certain sampling procedure. The main reason for that situation could be the random selection of unit's component, which is present at each of three observed sampling procedures. In that way, the difference between the estimated and population average is of a random nature. Consequently, the second research hypothesis which states that for the same sample sizes, the stratified random sampling achieves, on average, more accurate results than the simple random sampling and the two-stage cluster sampling, is rejected.

6. CONCLUSIONS

It is thought that there is no need to perform sampling in case of small populations. However, many problems can appear when we attempt to contact all population units. Furthermore, the costs of a research study on a small population can be very high. The time needed to collect the required data from all population units is not necessarily short. Finally, in case of small populations the sampling approach can sometimes be fully justified.

Because of its importance for the population of a country and for budget planning, total due liabilities for medicines in Croatian public hospitals on December 31st, 2014 are observed. The descriptive statistics analysis has shown that the value of total due liabilities for medicines in Croatian public hospitals has a high variability level across hospitals. Furthermore, the outlier analysis has detected an outlier or a public hospital which had total due liabilities for medicines significantly higher in comparison to other public hospitals.

In the further analysis, the simple random sampling, the stratified random sampling, and the two-stage cluster sampling procedures for different sample sizes are simulated. The analysis has shown that the first research hypothesis that in case of small populations in order to get satisfactory precision and accuracy levels of parameter estimates, at least 50% of population units should be sampled can only be partially accepted. Namely, the minimum recommended overall sampling rate, one which would result in satisfactory precision and accuracy levels of parameter estimates, at the simple random sampling and stratified random sampling is 70%. A researcher can expect to obtain relatively precise and accurate estimates if he samples more than 30% of population units when using the simple random sampling procedure, and more than 50% of population units when using the stratified random sampling procedure. On the other hand, two-stage cluster sampling failed to achieve a satisfactory precision and accuracy level for any observed sample size. The reason for that can be found in the fact that in the observed case a high heterogeneity level between clusters is present. Perhaps two-stage cluster sampling would be useful in cases where the heterogeneity level between clusters is relatively low. That should be closely investigated in the further research.

All three observed sampling procedures include the random sampling component which is more or less expressed. Consequently, the analysis has shown that there is no dominant and favoured sampling procedure when the accuracy of average estimates is observed. Therefore, the second research hypothesis was rejected.

In the further research, the authors will analyse more questions. In this paper, the focus was put only on one main question in the questionnaire. In reality, there are more key questions. So, in the further research the optimal sampling rate will take into account more questions for different sampling procedures. Furthermore, in this paper the authors assumed a 100% response rate. The problem of low response rates should be also taken into account in the future research of small population sampling.

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