A C T A   U N I V E R S I T A T I S   L O D Z I E N S I S
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ESTIMATION OF THE CORRUPTION PERCEPTION INDEX

Abstract. In the paper the results of the nonparametric estimation of the corruption perception index are presented. This nonparametric analysis consists of: kernel estimation of the density of this index and methods of interval mean estimation of the corruption perception index. Some of the regarded methods of interval estimation make use of additional information of the considered index (asymmetry or bounded random variable).

Key words: nonparametric analysis, kernel estimation, corruption perception index.

I. INTRODUCTION

The corruption perception index is a measure of phenomena of corruption, defined as the abuse of public power for private benefits and gain, among public officials and politicians in a particular country. This index is based on overall study of a number of surveys on perceiving corruption by entrepreneurs and analysts from given country as well as abroad. In that way the corruption perception index reflects the perceiving the phenomena of corruption in different countries. The corruption perception index is treated as one of the most relevant and the most reliable indexes of corruption (due to the diversity of data sources) and therefore it is widely used by researchers and specialists all over the world.

The corruption percepion index is worked out by the Secretary of Transparency International in Berlin and the University in Passau. It is a quantity from the interval [1,10]. The number 10 means the lack of corruption and 1 means full corruption. These indexes, determined for examined countries, allow to put the countries in order, because of the scale of perceived corruption.

The examination of corruption perception is madeannually since 1995. The number of countries participating in the study in the years 1995–2008 is various. There are countries that have never taken part in the survey of Transparency International and there are the countries that have abandoned their studies.

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In the paper some methods of estimation of the density function and some methods of inteval estimation of the mean of corruption perception index are presented. Regarded methods can be used for small samples. Such methods can be used in analysis of description of the index, especially in years when the number of countries patricipating in the study was small (for example 1995, 1997). Moreover, they may be used in future, if the number of countries covered by the survey declined.

In the estimation of density function of the corruption perception index, the kernel estimator (with Gaussian kernel function and smoothing parameter chosen using practical rules and cross-validation methods) is used.

In the mean interval estimation, some nonparametric methods are used: Fishman, Zhou–Dinh, bootstrap method based on percentiles and for large samples the classical method of interval estimation.

For the analysis of presented methods, in particular their efficiencies, data from 2008 were used. The corruption perception index was estimated on the basis of the so-called small samples (sample sizes: 10, 15, 20, 25 and 30).

II. ESTIMATION OF THE DENSITY FUNCTION OF THE CORRUPTION PERCEPTION INDEX

Let X be a continuous random variable with unknown density function *f(x)*. Let consider problem of estimation of the density function basedon a simple sample $X_1,...,X_n$. The estimator of the unknown function *f(x),* for which the *s*-th derivative (*s* is a fixed natural number) is continuous, may be the kernel estimator. It is defined by (e.g.: [6], [7]):

$$\hat{f}(x)=\frac{1}{nh}\sum_{i=1}^{n}K\left(\frac{x-X_i}{h}\right), \quad (1)$$

where $K(u)$ is the kernel function, and h is the smoothing parameter.

The kernel function $K(u)$ is the function satisfying the conditions:

$$\int_{-\infty}^{\infty}|K(x)|^2\,dx<\infty,\ K(x)=K(-x),\ \int_{-\infty}^{\infty}K(x)dx=1,$$

$$\sup_{-\infty<x<\infty}|K(x)|\le A<\infty,\ \int_{-\infty}^{\infty}x^iK(x)dx=0 \text{ for } i=1,...,s-1,$$

$$\int_{-\infty}^{\infty}x^sK(x)dx\neq 0,\ \int_{-\infty}^{\infty}x^sK(x)dx<\infty.$$

Smoothing parametr h is a function of sample size where: $h(n)>0$, $\lim_{n\to\infty} h(n)=0$ and $\lim_{n\to\infty} nh(n)=\infty$.

Kernel estimator (1) of density function is asymptotically unbiased and consistent estimator of density function.

Kernel estimator of the density function *f(x)* depends on the choice of the kernel function and the choice of the smoothing parameter. The literature includes examples of the kernel functions and the methods of the choice of the smoothing parameter (e.g.: [2], [4], [5]). In practice, the kernel functions which are symmmetric density functions are the most often used. For example, density function of the standarized normal distribution (Gaussian kernel function). Among the methods of the choice of the smoothing parameter special attention should appeal to the method of the reference of the standard distribution (very easy and simply approach) and methods of cross-validation (two kinds: least-squares cross validation and likelihood cross-validation).

Let X denotes the corruption perception index. In the estimation of the density function of the random variable X ,on the basis of n-element sample, the following Gaussian kernel function was used:

$$K(u)=\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}u^2} \tag{2}$$

The method of reference of the standard distribution for the choice of the smoothing parameter, known as the first rule of thumb, was used. According to this rule the smoothing parameter is defined as follows:

$$h=1.06\hat{\sigma}n^{-\frac{1}{5}}, \text{ where } \hat{\sigma}=\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i-\bar{x})^2} \tag{3}$$

The idea of the least-squares cross-validation is to minimize the score $CVNK(h)$ over h:

$$CVNK(h)=\frac{1}{n^2}\frac{1}{h}\sum_{i=1}^{n}\sum_{i=1}^{n}K*K\left(\frac{X_j-X_i}{h}\right)-2\frac{1}{n}\sum_{i=1}^{n}\frac{1}{n-1}\frac{1}{h}\sum_{j\neq i}^{n}K\left(\frac{X_i-X_j}{h}\right), \tag{4}$$

where $K*K(u)$ denotes the convolution kernel by itself. For the Gaussian kernel function this convolution is as follows:

$$K*K(u)=\frac{1}{2\sqrt{\pi}}\exp\left(\frac{-u^2}{4}\right). \tag{5}$$

The maximum likelihood cross-validation choice of h is to destignate such a value of h which maximizes the following function:

$$CVNW(h) = \frac{1}{n}\sum_{i=1}^{n}\log\left[\sum_{j\neq i}^{n} K\left(\frac{X_i - X_j}{h}\right)\right] - \log[(n-1)h] \tag{6}$$

The estimators of the density function of the the corruption perception index were determined based on the samples of selected sizes. For the sample size of 30 elements, with smoothing parameters chosen using (3), (4) and (6), the kernel estimators are presented in the figures 1–3.

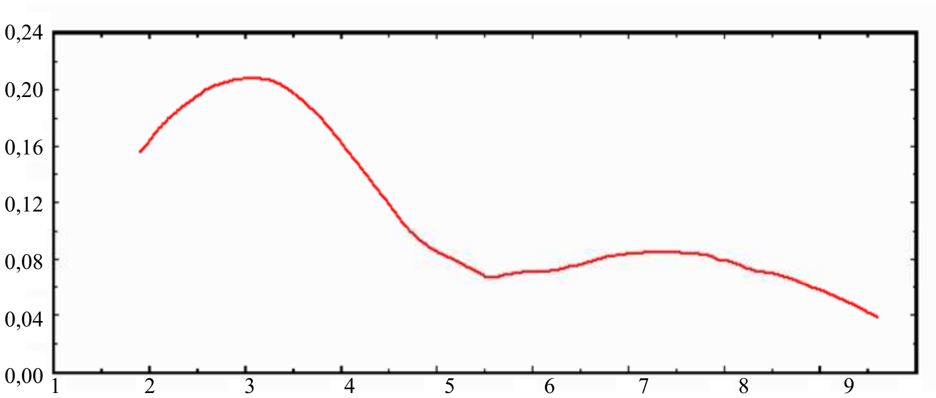

Figure 1: Estimator of the density function with smoothing parameter chosen by the reference of the standard distribution

Source: Own's calculations

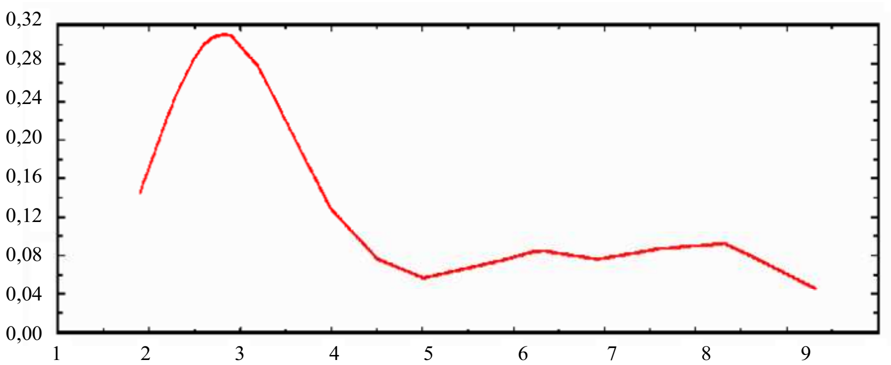

Figure 2: Estimator of the density function with smoothing parameter chosen by least-squares cross-validation.

Source: Own's calculations

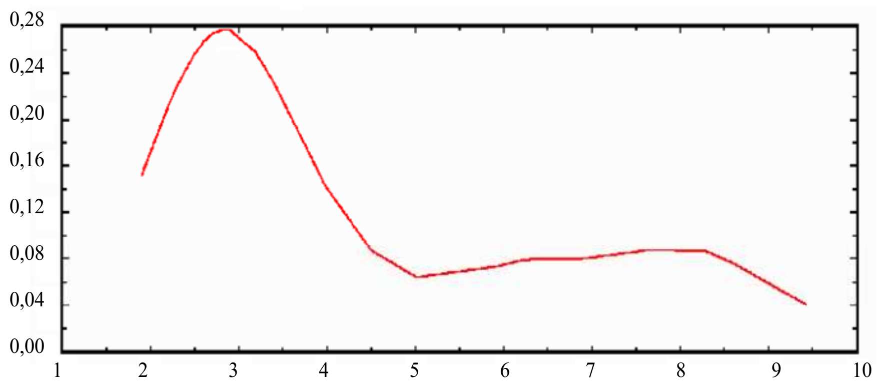

Figure 3: Estimator of the density function with smoothing parameter chosen by likelihood cross-validation

Source: Own's calculations.

The estimation of the density function of the corruption perception index, using 30-element sample size, gave the same results, regardless of the method of determing the smoothing parameter. In all cases, estimators of our unkown density function are not symmetrical. So, the authors assumed that regarded density function of the corruption perception index is asymmetric.

III. INTERVAL ESTIMATION OF THE MEAN OF THE CORRUPTION PERCEPTION INDEX

Let X be a random variable denoting the corruption perception index, and let μ be the mean of this variable.

Let us consider the problem of interval estimation of the mean μ, in the case of small samples. In addition, above consideration of the shape of density function and the application of the normality Shapiro-Wilk test, indicate the impossibility of assuming the normality distribution of the variable.

In the case of dependent sampling scheme, there is a possibility of using the following confidence interval:

$$P\left(\bar{x} - 3\frac{s}{\sqrt{n}}\sqrt{\left(1-\frac{n}{N}\right)} < \mu < \bar{x} - 3\frac{s}{\sqrt{n}}\sqrt{\left(1-\frac{n}{N}\right)}\right) \approx 0{,}9, \tag{7}$$

where N denotes the population size, n – the sample size, and $\bar{x}, s$ – arithmetic mean and standard deviation of the sample elements.

Probability that interval $(\bar{x}-3D, \bar{x}+3D)$, where D is the standard deviation of the arithmetic mean, cover the estimated mean with the probability, 0,9 is resulted from Czebyszev inequality $P\left(\left|X-EX\right|>k\sigma_X\right)<\frac{1}{k^2}$. For small samples, the sizes of the confidence intervals obtained in this way, are rather big.

Additional information about random variable such as the asymmetry of the distribution, or information about bounded random variable, cause that there is a possibility of construction nonclassical confidence interval for the mean of the corruption perception index. Using such nonclassical intervals may result in obtaining bigger accuracy of the estimation.

Using the information of distribution's asymmetry and estimating the asymmetry coefficient of the formula:

$$\hat{\gamma}_n = \frac{\frac{1}{n}\sum_{i=1}^{n}\left(x_i-\bar{x}_n\right)^3}{s_n^3},$$

where $x_1,...,x_n$ are the values of simple sample $X_1,...,X_n$, we can determine th confidence interval for the mean (e. g.: [8]):

$$P\left\{\bar{x}_n-\left[\sqrt[3]{1+3\left(\frac{u_{\alpha/2}}{\sqrt{n}}-\frac{\hat{\gamma}_n}{6n}\right)}-1\right]s_n\le\mu\le\bar{x}_n-\left[\sqrt[3]{1+3\left(-\frac{u_{1-\alpha/2}}{\sqrt{n}}-\frac{\hat{\gamma}_n}{6n}\right)}-1\right]s_n\right\}=1-\alpha \tag{8}$$

where:

$\bar{x}_n$ – arithmetic mean calculated in n-element sample,

s_n – standard deviation calculated in n-element sample,

$u_{\alpha/2}, u_{1-\alpha/2}$ – centiles of standarized normal distribution of order, respectively, $\frac{\alpha}{2}$ and $1-\frac{\alpha}{2}$.

Another property of the corruption perception index, that may be used in confidence interval of the mean μ, is the property of the bounded random variable – the corruption perception index takes the values from 1 to 10.

For a random variable Z from [0,1], Fishman proved the following inequality (e.g.: [3], [1]):

$$P\left(\mu_1(\bar{z}_n,n,\alpha) < \mu_Z < \mu_2(\bar{z}_n,n,\alpha)\right) \geq 1-\alpha\,, \tag{9}$$

where

μ_Z – the mean of the random variable Z,

$\bar{z}_n$ – arithmetic mean calculated from n-element sample $Z_1,\ldots,Z_n$,

$$\mu_1(\bar{z}_n,n,\alpha) = \begin{cases} 0 & \textit{for} \quad \bar{z}_n = 0 \\ t_1 & \text{for} \quad \bar{z}_n > 0 \end{cases}, \tag{10}$$

$$\mu_2(\bar{z}_n,n,\alpha) = \begin{cases} 1 & \text{for} \quad \bar{z}_n = 1 \\ t_2 & \text{for} \quad \bar{z}_n < 1 \end{cases}. \tag{11}$$

The values t_1, t_2 are the solutions of the equation:

$$n\bar{z}_n \ln\frac{t}{\bar{z}_n} + n(1-\bar{z}_n)\ln\frac{1-t}{1-\bar{z}_n} = \ln\frac{\alpha}{2} \tag{12}$$

And they satisfy the following inequalities: $0 < t_1 \leq \bar{z}_n \leq 1$ and $0 \leq \bar{z}_n < t_2 < 1$.

Generally, for continuous random variable X with support $[a,b]$, one can specify a variable $Z = \frac{X-a}{b-a}$, with support [0,1]. The confidence interval for the mean μ_Z of the variable Z can be obtained using the ends of the intevals from formulas (10) and (11).

Transforming the interval ($P\left(\mu_1(\bar{z}_n,n,\alpha) < \mu_z < \mu_2(\bar{z}_n,n,\alpha)\right) \geq 1-\alpha$) we can obtain the interval for the mean μ, for which the following inequality is fulfilled:

$$P\left(\mu_1(\bar{z}_n,n,\alpha)(b-a) + a < \mu < \mu_2(\bar{z}_n,n,\alpha)(b-a) + a \geq 1-\alpha\,. \tag{13}$$

For the corruption perception index, the random variable Z is the following:

$$Z = \frac{X-1}{9}.$$

And the confidence interval for the mean:

$$P(9\mu_1(\bar{z}_n,n,\alpha) + 1 < \mu < 9\mu_2(\bar{z}_n,n,\alpha) + 1) \geq 1-\alpha\,. \tag{14}$$

Another nonparametric procedure of estimation which allows to construct the confidence interval for the mean in the case of small sample is the bootstrap estimation based on the percentiles. The application of this method of estimation does not require additional assumptions about numerical characteristics or functional characteristic of the random variable.

In the bootstrap estimation, on the base of noncomplex sample $X_1, X_2, ..., X_n$, we construct N (for example N=10000) bootstrap samples $X_1^*, X_2^*, ..., X_n^*$ and calculate N values $\hat{\mu}^*$ which are the estimations of the parameter μ.

The confidence interval for the mean μ, constructed using the bootstrap method (e.g. [2]) is the following:

$$P\left(\hat{\mu}^{*\alpha/2} < \mu < \hat{\mu}^{*(1-\alpha/2)}\right) \approx 1-\alpha , \tag{15}$$

where $\hat{\mu}^{*\alpha/2}$, $\hat{\mu}^{*(1-\alpha/2)}$ are the percentiles of orders, respectively, $\frac{\alpha}{2}$ and $1-\frac{\alpha}{2}$ of the empirical distribution of the statistic $\hat{\mu}^*$ which is determined on the values generated according to the bootstrap distribution.

For the analysis of presented methods of confidence interval of the corruption perception index, the data from 2008 year were taken. They are published on the website of Transparency International Polska (http://www.transparency.pl). The small samples: n=10, 15, 20, 25, 30, were drawn and for each of these samples the confidence intervals (using three methods described above) were calculated for the confidence coefficients: 0,9; 0,95 and 0,99.

The table 1 presents arithmetic means, standard deviations and asymmetry coefficients calculated in drawn samples. The table 2 and 3 present the confidence intervals and the accuracy of estimation, which are calculated in samples for selected confidence coefficients. The accuracy of estimation is defined as half of the range of the confidence interval, is used to compare the analyzed methods.

Table 1: Estimated parameters on the base of samples

Sample size	$\overline{x}_n$	s_n	γ_n
10	4,070	2,213	0,913
15	4,053	2,086	0,813
20	4,090	2,020	0,861
25	4,212	2,065	0,812
30	4,550	2,331	0,721

Source: Own's calculations

Table 2: Confidence intervals and the accuracy of interval estimation of the mean of the corruption perception index for small samples

Method	$1-\alpha$	Sample size				
		10	15	20	25	30
Zhou – Dinh	0,9	(3,272; 8,161)	(3,406; 7,544)	(3,521; 7,070)	(3,687; 6,658)	(3,998; 5,858)
		2,445	2,069	1,744	1,485	0,930
	0,95	(3,159; 8,424)	(3,312; 8,144)	(3,446; 7,515)	(3,608; 7,469)	(3,914; 7,908)
		2,633	2,416	2,034	1,931	1,997
	0,99	(2,955; 8,813)	(3,140; 8,243)	(3,294; 7,947)	(3,462; 7,984)	(3,760; 8,634)
		2,929	2,551	2,394	2,261	2,437
Fishman	0,9	(1,660; 7,434)	(1,937; 6,503)	(2,165; 6,144)	(2,085; 6,399)	(2,796; 6,543)
		2,887	2,283	1,990	1,989	1,874
	0,95	(1,522; 7,746)	(1,761; 7,136)	(1,016; 6,785)	(2,258; 6,630)	(2,638; 6,751)
		3,112	2,687	2,384	2,186	2,056
	0,99	(1,310; 8,335)	(0,603; 7,407)	(0,840; 6,971)	(1,987; 7,078)	(1,497; 6,839)
		3,512	3,402	3,066	2,545	2,671
bootstrap	0,9	(3,04; 5,22)	(3,233; 4,967)	(3,390; 4,840)	(3,556; 4,892)	(3,877; 5,263)
		1,09	0,867	0,725	0,668	0,693
	0,95	(2,9; 5,44)	(3,087; 5,14)	(3,265; 4,995)	(3,44; 5,04)	(3,757; 5,410)
		1,27	1,027	0,865	0,800	0,827
	0,99	(2,66; 5,95)	(2,853; 5,487)	(3,035; 5,305)	(3,232; 5,296)	(3,563; 5,683)
		1,645	1,317	1,135	1,032	1,060

Source: Own's calculations.

Table 3: Confidence intervals and accuracy of interval estimation of the mean of the corruption perception index for large samples

Method	$1-\alpha$	Sample size			
		40	50	60	70
Zhou – Dinh	0,9	(3,932; 5,342)	(3,723; 4,957)	(3,674; 4,752)	(3,689; 4,633)
		0,705	0,617	0,539	0,472
	0,95	(3,855; 5,813)	(3,653; 5,238)	(3,609; 4,963)	(3,628; 4,806)
		0,979	0,793	0,677	0,589
	0,99	(3,716; 8,127)	(3,522; 7,596)	(3,489; 6,844)	(3,517; 5,374)
		2,205	2,037	1,678	0,928
Fishman	0,9	(2,886; 6,147)	(2,842; 5,717)	(2,852; 5,488)	(2,913; 5,357)
		1,630	1,446	1,310	1,222
	0,95	(2,745; 6333)	(2,699; 5,888)	(2,736; 5,640)	(2,803; 5,502)
		1,794	1,595	1,452	1,350
	0,99	(2,479; 6,700)	(2,462; 6,227)	(2,515; 5,958)	(2,593; 5,794)
		2,110	1,883	1,722	1,600
bootstrap	0,9	(3,855; 5,020)	(3,654; 4,714)	(3,615; 4,575)	(3,630; 4,497)
		0,583	0,530	0,480	0,434
	0,95	(3,755; 5,145)	(3,566; 4,822)	(3,525; 4,675)	(3,557; 4,587)
		0,695	0,628	0,575	0,515
	0,99	(3,550; 5,375)	(3,408; 5,046)	(3,363; 4,860)	(3,423; 4,744)
		0,913	0,819	0,748	0,661

Source: Own's calculations.

Obtained results may be compared with results from „classical method" of interval estimation in the case of dependent sampling scheme for confidence coefficient 0,9.

Table 4. The accuracy of estimation for small samples

Sample size	„classical" method	Zhou - Dinh	Fishman	bootstrap
10	2,055	2,445	2,887	1,090
15	1,564	2,069	2,283	0,867
20	1,297	1,744	1,990	0,725
25	1,172	1,485	1,989	0,668
30	1,194	0,930	1,874	0,693

Source: Own's calculations.

Table 5. The accuracy of estimation for small samples

Sample size	„classical" method	Zhou -Dinh	Fishman	bootstrap
40	0,994	0,705	1,630	0,913
50	0,878	0,617	1,446	0,819
60	0,767	0,539	1,310	0,748
70	0,668	0,472	1,222	0,661

Source: Own's calculations.

The obtained outcomes show that the best results we can get using the bootstrap method. For the sample n=30 there are two the best methods: the bootstrap and Zhou – Dinh method. Fishman method, in all regarded cases, causes that the length of the confidence intervals are the biggest. For larger samples Zhou – Dinh method causes that the length of the confidence intervals are the smallest.

The confidence intervals for the mean, for the regarded sample sizes, were obtained using one realization of the sample (tables 1–5). In order to generalize the results of the effectiveness „nonclassical" methods, each experiments was repeated 1000 times. The arithmetic mean of the accuracy of the estimation, for the selected sample sizes and for selected confidence coefficients were calculated. The results are presented in tables 6 and 7.

Table 6. Average accuracy of the interval estimation of the mean of the corruption perception index for small samples for 1000 repetitions

Method	$1-\alpha$	Sample size				
		10	15	20	25	30
Zhou – Dinh	0,9	2,3393	2,1236	1,9125	1,4504	0,8578
	0,95	2,5268	2,3329	2,1712	2,0113	1,8531
	0,99	2,8120	2,6256	2,4818	2,3519	2,2526
Fishman	0,9	2,8534	2,4434	2,1672	1,9650	1,8116
	0,95	3,0834	2,6579	2,3683	2,1536	1,9893
	0,99	3,4693	3,0454	2,7413	2,5089	2,3277
bootstrap	0,9	1,0084	0,8714	0,7673	0,6935	0,6384
	0,95	1,1909	1,0328	0,9104	0,8238	0,7587
	0,99	1,5266	1,3364	1,1834	1,0729	0,9900

Source: Own's calculations.

Table 7. Average accuracy of the interval estimation of the mean of the corruption perception index for large samples for 1000 repetitions

Method	$1-\alpha$	Sample size			
		40	50	60	70
Zhou – Dinh	0,9	0,6667	0,5695	0,5068	0,4612
	0,95	0,9299	0,7381	0,6406	0,5755
	0,99	2,0816	1,8960	1,5845	0,9068
Fishman	0,9	1,5897	1,4327	1,3146	1,2213
	0,95	1,7501	1,5797	1,4510	1,3490
	0,99	2,0594	1,8655	1,7176	1,5996
bootstrap	0,9	0,5510	0,4979	0,4550	0,4214
	0,95	0,6552	0,5922	0,5416	0,5015
	0,99	0,8570	0,7751	0,7097	0,6574

Source: Own's calculations.

Comparing obtained results we can state that the best estimation was received using bootstrap method. The lengths of the confidence intervals, constructed in that way, are even more than twice smaller than in the case of Zhou-Dinh's intervals (with the same confidence coefficients). But for samples larger than 30, Zhou-Dinh method appeared more efficient.

Comparing the bootstrap estimation with the Fishman one, results in the same conclusions. But it must be taken into consideration that the Fishman's confidence intervals include the estimated mean with the confidence no less than the value $1-\alpha$. The Fishman's and Zhou-Dinh's confidence intervals for the sample of 10, 15 elements have the lengths close to the range of the support of the regarded random variable ([1,10]).

Of course, using any of these methods, with increased confidence coefficient, the accuracy of the estimation decreases, but with the increasing of the sample size, the accuracy of the estimation increases.

Obtained results are consistent with previous results of the biggest accuracy of estimation using bootstrap and Zhou – Dinh method.

IV. FINAL CONCLUSIONS

The methods of estimation of the corruption perception index are nonparametric methods. The advantage of these methods is the possibility of their use in the absence of information about the class, which includes the distribution of the analyzed variable.

Nonparametric methods of mean estimation, using information about the asymmetry of the distribution of the random variable (Zhou-Dinh method), or about the property of the bounded random variable (Fishman method), used for small samples proved to be inefficient (in the case of interval mean estimation of the corruption perception index).

The highest accuracy of the estimation of the mean of the perception corruption index was obtained by bootstrap method based on the percentiles. An important advantage of the bootstrap method is the possibility of its application without the need to include additional information on a random variable. In addition, it can be used in estimation using samples of different sizes. The possibility of applying the bootstrap method in the estimation of the numerical characteristics of the random variable using small samples. Further studies should therefore be given to other bootstrap methods of estimation such as: t-bootstrap estimation, two-stages bootstrap estimation, which may result in receiving much better estimation (with better accuracy).

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ESTYMACJA WSKAŹNIKA PERCEPCJI KORUPCJI

W pracy przedstawiono wyniki nieparametrycznej analizy wskaźnika percepcji korupcji. Na analizę tę składa się metoda jądrowa estymacji funkcji gęstości oraz wybrane metody estymacji przedziałowej wartości średniej wskaźnika percepcji korupcji. Do rozważanych metod estymacji wartości średniej należą: jedna z metod bootstrapowych oraz metody wykorzystujące dodatkowe informacje o zmiennej takie jak asymetria rozkładu, ograniczoność zbioru wartości zmiennej.

Przeprowadzona analiza dotyczy estymacji wskaźnika percepcji korupcji w 2008 roku różnymi metodami, w oparciu o próby proste różnej liczebności. Porównanie uzyskanych wyników estymacji pozwoliło sformułować wnioski dotyczące dokładności oszacowań, a tym samym efektywności rozpatrywanych metod.