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COM O ALTO PATROCÍNIO
DE SUA EXCELÊNCIA
UNDER THE HIGH PATRONAGE OF THE
PRESIDENT OF THE PORTUGUESE REPUBLIC



O Presidente da República

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Key words and phrases: Poverty line, missing information, household surveys, developing countries.

The Use of Calibration and Integrated Weighting Techniques in Poverty and Inequality Analysis

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Abstract: Most poverty and inequality analyses rely on household-based surveys, such as the income and expenditure surveys, which are generally conducted by selecting a sample of households and then including all members of the household, in the sample. Since multistage stratified sampling is used for these surveys, and coverage errors and non-response are generally part of surveys, it is essential that the survey data need to be weighted in order to get the right estimates of measures such as mean income and poverty rates. Both person and household characteristics, such as age, geographical area (urban/rural) as well as household size and composition are determinants of income and would be of importance to include in this final step of weighting. This paper considers the use of the calibration technique, which is based on weighting at person level auxiliary information only, as well as integrated weighting techniques, where person and household auxiliary variables could be used simultaneously, in poverty and inequality analysis. The Income and Expenditure Survey (IES) 2000, compiled by Statistics South Africa, is used to compare poverty and inequality measures such as Headcount index, Gini coefficient and Theil's index, based on the different sets of weights. Variance estimation and the precision for the income estimator in complex surveys will also be considered.

Key words and phrases: Auxiliary information, complex sampling, income and expenditure survey, income estimator, poverty and inequality measures.

Minimum Sample Sizes in Asymptotic Confidence Intervals for Gini's Concentration Index

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Abstract: Statistical inference for concentration measures has been of considerable interest in recent years. Income studies often deal with very large samples, hence precision would not seem a serious issue. Yet, in many empirical studies large standard errors are observed, and methodologies for assessing the statistical significance of differences between estimates are required. This paper presents an analysis of the performance of asymptotic confidence intervals for Gini's index, virtually the most widely used concentration index. In order to determine minimum sample sizes assuring a given accuracy in confidence intervals, an extensive simulation study has been carried out. As expected, the minimum sample sizes are seriously affected by some population characteristics, mainly by heavy tails and asymmetry. However, it turns out that in a wide range of cases they are smaller than most of the sample sizes actually used in social sciences.

Key words and phrases: Gini's concentration measure, asymptotic confidence intervals.

A Subgroups Decomposition of a New Inequality Index Proposed by Zenga

Minimum Sample Sizes in Asymptotic Confidence Intervals for Gini's Concentration Index

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Statistical inference for concentration measures has been of considerable interest in recent years. Income studies often deal with very large samples, hence precision would not seem a serious issue. Yet, in many empirical studies large standard errors are observed, and it is therefore important to provide methodologies Author1990to assess whether differences in estimates are statistically significant. This work focuses on Gini's concentration ratio R . Hoeffding, in his seminal work (Hoeffding,1948), derived the asymptotic distribution of Gini's index. Several years later, Giorgi and Provasi (1995) and Palmitesta *et al.* (1999) pointed out that the speed of convergence of the sample distribution is rather slow. Further studies (Palmitesta *et al.* (2000), and Giorgi *et al.* (2006)) revealed that the t-bootstrap method yields more accurate confidence intervals in small samples. Bootstrap methods are however computationally expensive; moreover, the difference with respect to the asymptotic approach becomes less significant as the sample size increases. In inference studies involving large samples, (i.e. income surveys), it seems therefore reasonable to retain the asymptotic approach. Latorre (1990) showed that sample sizes currently in use are large enough for constructing confidence intervals based on the maximum likelihood estimator for Gini's concentration measure. Are they also adequate to assure a good coverage of asymptotic non parametric confidence intervals? This work's aim is to provide an answer to this question.

Confidence intervals for Gini's concentration index

It is well known that the Gini concentration index R may be expressed as ratio of two regular functionals, the Gini mean difference Δ and twice the mean μ . Let X_1, \dots, X_n be i.i.d. with unknown distribution function F , whose variance σ^2 is assumed to exist. Let $\hat{\Delta}$ be the (unbiased) sample mean difference, \bar{X} the sample mean and $\hat{R} = \hat{\Delta}/(2\bar{X})$ the sample Gini concentration ratio. In an application of his asymptotic distribution theory for U-statistics, Hoeffding (1948) proved that, if

$$\sigma_R^2 = \lim_{n \rightarrow \infty} \sigma_{R,n}^2 = \lim_{n \rightarrow \infty} \left\{ \frac{1}{4\mu^2} n \text{Var}(\hat{\Delta}) + \frac{\Delta^2}{4\mu^4} \sigma^2 - \frac{\Delta}{2\mu^3} n \text{Cov}(\bar{X}, \hat{\Delta}) \right\} > 0$$

then

$$\sqrt{n} \left(\frac{\hat{R} - R}{\sigma_{R,n}} \right) \xrightarrow{d} N(0, 1).$$

Now, $\text{Var}(\hat{\Delta})$ and $\text{Cov}(\bar{X}, \hat{\Delta})$ may be expressed as (Zenga *et al.* (2004); Poliscchio and Zenga (1995))

$$\text{Var}(\hat{\Delta}) = \frac{4}{n(n-1)} \left[\sigma^2 + (n-2)\mathcal{F} - \frac{2n-3}{2}\Delta^2 \right], \quad \text{Cov}(\bar{X}, \hat{\Delta}) = \frac{2}{n} (\mathcal{D} - \mu\Delta),$$

where

$$\mathcal{F} = \int \int \int |x_1 - x_2| |x_1 - x_3| dF(x_1) dF(x_2) dF(x_3), \quad \mathcal{D} = \int \int x_1 |x_1 - x_2| dF(x_1) dF(x_2).$$

Since variances and covariances of U-statistics are regular functionals, the variance σ_R^2 can be consistently estimated from the sample data, provided the second moment of the underlying distribution is finite (see Lee (1990), p.122, theorem 3). In particular, the unbiased estimators

$$\widehat{Var}(\widehat{\Delta}) = \frac{4}{(n-2)(n-3)} \left[S^2 + (n-2)\widehat{\mathcal{F}} - \frac{2n-3}{2}\widehat{\Delta}^2 \right], \quad \widehat{Cov}(\overline{X}, \widehat{\Delta}) = \frac{2}{n-2}(\widehat{\mathcal{D}} - \overline{X}\widehat{\Delta}).$$

may be used, where S^2 is the unbiased variance estimator and $\widehat{\mathcal{F}}, \widehat{\mathcal{D}}$ are the U-statistics corresponding to \mathcal{F} and \mathcal{D} :

$$(1) \quad \widehat{\mathcal{F}} = \frac{\sum_{i \neq j \neq k} |X_i - X_j| |X_i - X_k|}{n(n-1)(n-2)}, \quad \widehat{\mathcal{D}} = \frac{\sum_{i \neq j} X_i |X_i - X_j|}{n(n-1)}.$$

It follows that

$$\widehat{\sigma}_R^2 = \frac{1}{4\overline{X}^2} n \widehat{Var}(\widehat{\Delta}) + \frac{\widehat{\Delta}^2}{4\overline{X}^4} S^2 - \frac{\widehat{\Delta}}{2\overline{X}^3} n \widehat{Cov}(\overline{X}, \widehat{\Delta})$$

is a strongly consistent estimator for σ_R^2 . Writing z_p to mean the p-th quantile of the standard normal distribution, it follows that the interval

$$(2) \quad \left(\widehat{R} - \frac{\widehat{\sigma}_R}{\sqrt{n}} z_{1-\alpha/2}; \widehat{R} + \frac{\widehat{\sigma}_R}{\sqrt{n}} z_{1-\alpha/2} \right)$$

contains the true value of Gini's concentration index with probability approximately equal to $1 - \alpha$, provided the sample size is large enough.

It is worth noting that direct use of the formulae in (1) implies a computation time of $O(n^3)$ for $\widehat{\mathcal{F}}$ and of $O(n^2)$ for $\widehat{\Delta}$ and $\widehat{\mathcal{D}}$. Average computation time can, however, be drastically reduced to $O(n \ln n)$ using the order statistics (see Zenga *et al.* (2004); Poliscchio and Zenga (1995)).

Simulation study

This section determines the minimum sample sizes such that the coverage probability of the confidence interval in (2) is reasonably close to the nominal confidence level $1 - \alpha$. For this purpose a simulation study has been performed, using the software package R. The procedure may be summarized by the following steps: (I) Fix the sample size n . The sample sizes considered in this analysis vary between 30 and 3840. (II) Draw $N = 5000$ samples of size n , fixed at the previous step. The choice of N has to take into account two opposite requirements. On one hand, N as large as possible to give a better representation of the simulated sample space, and, on the other hand, N bounded to limit computation time. (III) For each sample compute the confidence interval (2), and check whether it contains the true value of the Gini concentration index. The proportion of intervals satisfying this condition provides an estimate for the unknown coverage probability.

The estimates \widehat{p}_n of the unknown coverage probabilities p_n will be used to determine minimum sample sizes as in Greselin and Maffinini (2007). In general, the effective unknown coverage depends on the chosen sample size n , the confidence level $1 - \alpha$, and the underlying distribution F . In any case, $\lim_{n \rightarrow \infty} p_n = 1 - \alpha$. Assuming that (as in most applications) some coverage error $\gamma > 0$ with respect to the nominal confidence level $1 - \alpha$ is tolerable, let $H_0 : p_n \geq 1 - \alpha - \gamma$ be the hypothesis that the sample size n is sufficiently large. H_0 will be rejected if

$$\widehat{p}_n < 1 - \alpha - \gamma - z_{0.95} \sqrt{\frac{(1 - \alpha - \gamma)(\alpha + \gamma)}{N}}.$$

Since for large values of N the estimated coverage probability \hat{p}_n is approximately normally distributed, the rejection probability is roughly bounded by 0.05 under H_0 . Taking $N = 5000$, $\gamma = 0.1\alpha$ and $\alpha = 0.05$, this procedure leads to rejection of H_0 if $\hat{p}_n < 0.9397$. If $\alpha = 0.01$, H_0 will be rejected if $\hat{p}_n < 0.9866$.

The distributions considered in the simulations are reported in table 1. The parameters were chosen to lie in a neighborhood of the maximum likelihood estimates yielded on real income distributions.

distribution	density function $f(x)$		acronim	parameter values	
Lognormal	$\frac{1}{\delta\sqrt{2\pi}} \frac{1}{x} \exp^{-\frac{1}{2}\left(\frac{\ln x - \gamma}{\delta}\right)^2}$	$x > 0,$	(logA)	$\gamma = 10, \delta = 0.35829$	
			$\delta > 0, \gamma \in \mathbb{R}$	(logB)	$\gamma = 10, \delta = 0.5$
				(logC)	$\gamma = 10, \delta = 0.74161$
Pareto	$\theta x_0^\theta x^{-(\theta+1)}$	$x > x_0, \theta > 0$	(ParA)	$x_0 = 1, \theta = 5$	
				(ParB)	$x_0 = 1, \theta = 3$
				(ParC)	$x_0 = 1, \theta = 2.5$
Dagum	$\beta\lambda\theta x^{-\theta-1} \left(1 + \frac{\lambda}{x^\theta}\right)^{-\beta-1}$	$x > 0$	(DagA)	$\lambda = 1, \beta = 1, \theta = 5$	
			$\beta, \lambda, \theta > 0$	(DagB)	$\lambda = 1, \beta = 1, \theta = 3$
				(DagC)	$\lambda = 1, \beta = 1, \theta = 2.5$

Table 1: Parent distributions for simulations

Table 2 reports the estimates of the coverage probabilities of the 95% and the 99% confidence intervals. Boldfaced figures are estimated coverage probabilities that lie in the acceptance region of H_0 .

The main result is that the minimum sample sizes increase drastically as the right tail of the parent distribution becomes heavier: if all moments of the parent distribution are finite, as in the Lognormal case, samples of size 480 are sufficient to obtain accurate confidence intervals. If the parent distribution has only a finite number of moments, as in the Dagum and Pareto case, the thresholds are much larger. In extreme cases, i.e. if the third moment of the parent distribution is not finite, none of the considered sample sizes appears to be sufficient.

The simulation results obtained on the Lognormal model, allow to assess the effect of asymmetry in the underlying distribution. In fact, as the value of the parameter δ increases, the Lognormal distribution becomes more asymmetric, and the estimated coverage probability steadily decreases.

As expected, also the nominal confidence level affects the minimum sample size: smaller values of α , require larger sample sizes to yield an acceptable accuracy.

Conclusions

This paper investigates minimum sample sizes for accurate confidence intervals for Gini's concentration measure. A simulation study shows that they are seriously affected by tail-heaviness and asymmetry in the underlying distribution. Let alone extreme cases, it appears that samples of size larger than 3840 units yield accurate confidence intervals at nominal confidence levels up to 0.99. This insight seems to be of interest in income studies, where sample sizes of several thousand statistical units are customary.

95% confidence interval									
n	logA	logB	logC	DagA	DagB	DagC	ParA	ParB	ParC
30	0.9104	0.9048	0.8858	0.8944	0.8524	0.8212	0.8362	0.7738	0.7572
60	0.9298	0.9230	0.9068	0.9136	0.8708	0.8376	0.8746	0.8256	0.8034
120	0.9380	0.9322	0.9244	0.9278	0.8926	0.8698	0.8974	0.8722	0.8456
240	0.9422	0.9392	0.9322	0.9362	0.9094	0.8894	0.9158	0.8920	0.8610
480	0.9486	0.9478	0.9440	0.9422	0.9248	0.9108	0.9324	0.9154	0.8942
960	0.9484	0.9482	0.9402	0.9472	0.9310	0.9132	0.9374	0.9330	0.9106
1920	0.9480	0.9478	0.9466	0.9428	0.9394	0.9272	0.9444	0.9350	0.9208
3840	0.9476	0.9542	0.9518	0.9456	0.9478	0.9314	0.9460	0.9426	0.9288
99% confidence interval									
30	0.9650	0.9602	0.9498	0.9510	0.9202	0.8948	0.8968	0.8484	0.8254
60	0.9738	0.9742	0.9604	0.9650	0.9350	0.9176	0.9306	0.8944	0.8744
120	0.9842	0.9808	0.9744	0.9756	0.9518	0.9378	0.9516	0.9292	0.9120
240	0.9864	0.9816	0.9818	0.9798	0.9604	0.9532	0.9672	0.9486	0.9294
480	0.9902	0.9876	0.9848	0.9862	0.9710	0.9646	0.9772	0.9658	0.9508
960	0.9898	0.9874	0.9854	0.9858	0.9802	0.9686	0.9806	0.9738	0.9642
1920	0.9870	0.9892	0.9886	0.9870	0.9806	0.9736	0.9882	0.9776	0.9728
3840	0.9864	0.9898	0.9912	0.9872	0.9848	0.9800	0.9876	0.9832	0.9756

Table 2: Estimated coverage probabilities

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