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TEST PROCEDURES WITH SELECTED RANKED SET SAMPLING

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1. INTRODUCTION

Hossain and Muttlak (2001) suggested the selected ranked set sampling (SRSS) method which is one of the several modifications of the ranked set sampling (SRS) method (see, for example, McIntyre 1952, Takahasi and Wakimoto 1968). This method, like the usual RSS method and, and its modifications (see for example Muttlak 1997, Hossain and Muttlak 1999, Hossain 2001) can be used in many ecological, environmental and agricultural studies where it is very difficult or expensive to measure the sampling units but the units can easily be ranked. In this method some selected observations are used from each of a number of randomly selected sets for quantification. The selection of the observations to be quantified are done by a parametric manner and parametric estimators of the population mean and standard deviation are obtained. The main advantages of this method over the usual ranked set sampling (RSS) are:

i. the efficiency of the parametric estimator of the population mean obtained by this method is very high with respect to the usual RSS mean,
ii. an estimator of the population standard deviation can be obtained using the SRSS method, which in case of the RSS method could not be obtained without replicating the design,
iii. both in the RSS an the SRSS methods, visually ranked observations from sets of random observations are quantified, the set size in the RSS method is required to be the same as the sample size, but in the SRSS method the set size n does not depend on the sample size, and hence any set size can be chosen with the freedom of the experimenter,
iv. though being parametric procedure, the SRSS method in case of some known distributions is not sensitive to the departure from the underlying assumption of the distribution.

But since the SRSS method utilizes parametric point estimation of the population parameters, proper test procedures are required to support such estimation. Hossain (2000) described some test procedures using MRSS data from the uniform and exponential populations. Similar procedures using RSS data were demonstrated by Abu-Dayyeh and Muttlak (1996). Muttlak and Abu-Dayyeh (1998) also described test procedures using RSS data from the normal population. For details on such test procedures see Hossain (1999).

In this paper, test procedures for the scale parameter of the unifom and exponntial distributions using SRSS data are discussed. The necessay values for the critical regions for the suggested tests using SRSS data are computed using a simulation and are supplied in tabular form, also the powers of the tests for specified size $\alpha = 0.05$ are investigated by a computer simulation.

2. SAMPLING METHOD

The procedure for drawing a SRSS of size lm can be described as follows:

l sets of $n > l$ elements is randomly drawn and the elements in each set are ordered by visual inspection and then the n_i^{th} smallest element in the n_i^{th} $(\mathrm{i} = 1,2, \ldots ,\mathrm{l})$ set is measured. The values of $n_1, n_2, \ldots, n_l$ $(1 \le n_1 \le n_2 \le \ldots \le n_l \le n)$ are required to be determined beforehand depending on the underlying distribution is known. The procedure can be repeated m times to obtain a sample of size lm. Hossain and Muttlak (2001) suggested the optimal linear estimators of the location and scale parameters using the SRSS data. They also supplied the choice of $n_1, n_2, \ldots, n_l$ $(1 \le n_1 \le n_2 \le \ldots \le n_l \le n)$, and associated coefficients for the linear estimators of the location and scale parameters for different distributions.

3. TEST PROCEDURES USING SRSS DATA

Let the sample s be drawn using the SRSS method described in the section 2. Let the sample size be lm, where l selected observations from sets of size n are quantified in m cycles. We have

$$s = \begin{Bmatrix} X_{(n_1,n)11} & X_{(n_2,n)21} & \cdots & X_{(n_l,n)l1} \\ X_{(n_1,n)12} & X_{(n_2,n)22} & \cdots & X_{(n_l,n)l2} \\ \cdots & \cdots & \cdots & \cdots \\ X_{(n_1,n)1m} & X_{(n_2,n)2m} & \cdots & X_{(n_2,n)lm} \end{Bmatrix} \qquad (1)$$

where $X_{(i,n)jr}$ denote the i^{th} smallest order statistic in the j^{th} random set of size n in the r^{th} cycle. For simplicity we write $Y_{ij} = X_{(n_i,n)ij}$. Then the sample s becomes,

$$s=\begin{Bmatrix} Y_{11} & Y_{21} & \ldots & Y_{l1} \\ Y_{12} & Y_{22} & \ldots & Y_{l2} \\ \ldots & \ldots & \ldots & \ldots \\ Y_{1m} & Y_{2m} & \ldots & Y_{lm} \end{Bmatrix} \tag{2}$$

3.1 *Test 1 for Scale Parameter of a Uniform Distribution*

Let s be drawn from the uniform distribution with probability density function

$$f_\theta(x)=\begin{cases}\dfrac{1}{\theta} & 0\le x\le\theta \\ 0 & otherwise\end{cases} \tag{3}$$

The corresponding cumulative distribution function (*cdf*) is given as

$$F_\theta(x)=\int_0^x f_\theta(x)dx=\begin{cases}\dfrac{x}{\theta} & 0\le x\le\theta \\ 0 & otherwise\end{cases}\ . \tag{4}$$

Now let the following hypothesis concerning the scale parameter θ be intended to be tested

$$\begin{aligned} H_0: &\quad \theta=\theta_0 \\ H_a: &\quad \theta\ne\theta_0 \end{aligned} \tag{5}$$

Without loss of generality, we can assume that $\theta_0=1$. The Test 1 for testing the hypothesis (5) can be given as

$$\phi_1(x)=\begin{cases}1 & if\ \max\{Y_{ij}\}<c_1\ or\ \max\{Y_{ij}\}>1 \\ 0 & Otherwise\end{cases} \tag{6}$$

with

$$\begin{aligned}\alpha &= P_{\theta=1}(\max\{Y_{ij}\}<c_1) \\ &=\prod_{j=1}^{m}\prod_{i=1}^{l}P_{\theta=1}(Y_{ij}<c_1)\end{aligned} \tag{7}$$

Now the Y_{ij} s are the n_i^{th} smallest order statistics from samples of size n in the i^{th} set of the j^{th} cycle. Using distribution of n_i^{th} order statistic (see for example, Balakrishnan and Cohen 1991) and equations (3) and (4), $\forall j = 1, 2, \ldots, m$, we can write

$$f_{n_i:n}(y_{ij}) = \begin{cases} \dfrac{n!}{(n-n_i)!(n_i-1)!}\left(\dfrac{y_{ij}}{\theta}\right)^{(n-n_i)}\left(1-\dfrac{y_{ij}}{\theta}\right)^{(n_i-1)}\dfrac{1}{\theta} & 0 \le y_{ij} \le \theta \\ 0 & otherwise \end{cases} \tag{8}$$

Now, we have

$$\begin{aligned} \alpha &= \prod_{j=1}^{m}\prod_{i=1}^{l} P_{\theta=1}(Y_{ij} < c_1) \\ &= \prod_{j=1}^{m}\prod_{i=1}^{l}\left\{\int_0^{c_1}\frac{n!}{(n-n_i)!(n_i-1)!}(y_{ij})^{(n-n_i)}(1-y_{ij})^{(n_i-1)}dy_{ij}\right\} \\ & \qquad 0 \le y_{ij} \le 1 \end{aligned} \tag{9}$$

The power function of the test in (6) is given by

$$1-\beta_{\phi_1}(\theta) = \begin{cases} 1 & if \quad \theta \le c_1 \\ \prod_{j=1}^{m}\prod_{i=1}^{l} P_{\theta=1}(Y_{ij} < c_1) & if \quad c_1 < \theta \le 1 \\ \prod_{j=1}^{m}\prod_{i=1}^{l} P_{\theta=1}(Y_{ij} < c_1) + 1 - \prod_{j=1}^{m}\prod_{i=1}^{l} P_{\theta=1}(Y_{ij} < 1) & if \quad \theta > 1 \end{cases} \tag{10}$$

For the SRSS method, the values of c_1 for different values of α are given in Table 1 for $l \le n \le 7$ and $m = 1$. The power functions of the test (6) is computed for $l \le n \le 7$ and $m = 1$, and for fixed $\alpha = 0.05$ and is given in Table 2.

TABLE 1

Critical values for Test 1 with SRSS data from the uniform distribution

		α						
n	l	.001	.005	.010	.025	.050	.100	.250
3	2	0.1401	0.2136	0.2569	0.3296	0.3997	0.4871	0.6401
4	2	0.2025	0.2867	0.3341	0.4107	0.4818	0.5674	0.7084
	3	0.3289	0.4132	0.4571	0.5241	0.5831	0.6511	0.7594
5	2	0.2638	0.3549	0.4044	0.4819	0.5513	0.6318	0.7580
	3	0.4091	0.4926	0.5347	0.5974	0.6509	0.7111	0.8039
	4	0.4256	0.5044	0.5443	0.6038	0.6553	0.7136	0.8046
6	2	0.3217	0.4164	0.4659	0.5416	0.6074	0.6814	0.7938
	3	0.4757	0.5559	0.5951	0.6527	0.7009	0.7542	0.8346
	4	0.4819	0.5594	0.5978	0.6541	0.7017	0.7545	0.8347
	5	0.5252	0.5942	0.6281	0.6778	0.7200	0.7671	0.8402
7	2	0.3748	0.4700	0.5184	0.5906	0.6519	0.7197	0.8204
	3	0.5304	0.6061	0.6426	0.6951	0.7387	0.7862	0.8571
	4	0.5325	0.6070	0.6431	0.6954	0.7388	0.7862	0.8571
	5	0.5770	0.6417	0.6730	0.7183	0.7562	0.7982	0.8622
	6	0.5816	0.6444	0.6749	0.7194	0.7569	0.7984	0.8623

TABLE 2

Power of Test 1 with SRSS data from the uniform distribution ($\alpha = 0.05$)

		θ							
n	l	0.50	0.75	0.90	1.10	1.25	1.50	3.00	5.00
3	2	0.5067	0.1359	0.0726	0.2849	0.5146	0.7261	0.9748	0.9962
4	2	0.8622	0.1675	0.0783	0.3502	0.6100	0.8133	0.9904	0.9991
	3	1.0000	0.2856	0.0970	0.3739	0.6765	0.8877	0.9989	1.0000
5	2	1.0000	0.2143	0.0855	0.4097	0.6882	0.8749	0.9966	0.9998
	3	1.0000	0.4369	0.1139	0.4440	0.7665	0.9412	0.9998	1.0000
	4	1.0000	0.4461	0.1173	0.4441	0.7672	0.9436	0.9999	1.0000
6	2	1.0000	0.2821	0.0944	0.4636	0.7508	0.9165	0.9988	1.0000
	3	1.0000	0.6303	0.1346	0.5090	0.8337	0.9700	1.0000	1.0000
	4	1.0000	0.6357	0.1357	0.5096	0.8337	0.9705	1.0000	1.0000
	5	1.0000	0.7650	0.1546	0.5129	0.8488	0.9797	1.0000	1.0000
7	2	1.0000	0.3748	0.1046	0.5125	0.8007	0.9444	0.9996	1.0000
	3	1.0000	0.8951	0.1592	0.5691	0.8827	0.9850	1.0000	1.0000
	4	1.0000	0.8960	0.1594	0.5690	0.8827	0.9851	1.0000	1.0000
	5	1.0000	1.0000	0.1861	0.5748	0.8991	0.9914	1.0000	1.0000
	6	1.0000	1.0000	0.1879	0.5745	0.8994	0.99148	1.0000	1.0000

3.2 *Test 2 for Scale Parameter of an Exponential Distribution*

Consider the case where the sample s be drawn from an exponential distribution using the SRSS method. The *pdf* and the *cdf* are then given by

$$f_\theta(x) = \begin{cases} \dfrac{1}{\theta} e^{-\frac{x}{\theta}} & x \geq 0 \\ 0 & otherwise \end{cases}, \tag{11}$$

and

$$F_\theta(x) = \int_0^x f_\theta(t)dt = \begin{cases} 1 - e^{-\frac{x}{\theta}} & x \geq 0 \\ 0 & otherwise \end{cases} \tag{12}$$

respectively.

Also let the following hypothesis concerning the scale parameter θ be intended to be tested

$$\begin{aligned} H_0 &: \quad \theta = \theta_0 \\ H_a &: \quad \theta > \theta_0 \end{aligned} \tag{13}$$

Without loss of generality, we can assume that $\theta_0 = 1$. Now the Test 2 with size α for testing the hypothesis (13) can be written as

$$\phi_2(x) = \begin{cases} 1 & if \ \sum_{j=1}^{m}\sum_{i=1}^{l} Y_{ij} > c_2 \\ 0 & Otherwise \end{cases} \tag{14}$$

Again, using equations (11) and (12), we can write the distribution function of Y_{ij}, the n_i^{th} smallest order statistic. Let $f_{n_i}(y_{ij})$ denote the density function, then

$$f_{n_i}(y_{ij}) = \begin{cases} \dfrac{n!}{(n_i-1)!(n-n_i)!}\left(1-e^{-\frac{y_{ij}}{\theta}}\right)^{(n_i-1)}\left(e^{-\frac{y_{ij}}{\theta}}\right)^{(n-n_i)}\dfrac{1}{\theta}e^{-\frac{y_{ij}}{\theta}} & y_{ij} \geq 0 \\ 0 & otherwise \end{cases} \tag{15}$$

Using equation (15), the distribution of $W_l = \sum_{j=1}^{m}\sum_{i=1}^{l} Y_{ij}$ can be obtained by successive application of the transformations $Z_{ij} = \sum_{i=1}^{j} Y_{ij}$ and $W_j = \sum_{m=1}^{j} Z_{im}$. Denoting $k_{*\theta}(w_l)$ as the distribution of W_l, the power function of the test (14) is given by

$$\beta_{\phi_2} = P_\theta\left(\sum_{j=1}^{m}\sum_{i=1}^{l} Y_{ij} > c_2\right) = \int_{c_2}^{\infty} k_{*\theta}(w_l)\,dw_l \,. \tag{16}$$

The values of c_2 for fixed α can be obtained by solving the equation

$$\alpha = \beta_{\phi_2}(1) = \int_{c_2}^{\infty} k_{*\theta(\theta=1)}(w_l)\,dw_l \,. \tag{17}$$

The distribution $k_{*\theta(\theta=1)}(w_l)$ of W_l can be evaluated by numerical integration and hence the values of c_2 and β_{ϕ_2} can be obtained. The values of c_2 for different values of α are given in Table 3 for $l \leq n \leq 7$ and $m = 1$. Also the power function of the test (14) is computed for $l \le n \le 7$ and $m = 1$, and for fixed $\alpha = 0.05$ and is given in Table 4.

TABLE 3

Critical values for Test 2 with SRSS data from the exponential distribution

n	l	α .001	.005	.010	.025	.050	.100	.250
3	2	8.4113	6.8001	6.1048	5.1818	4.4773	3.7611	2.7701
4	2	8.5813	6.9701	6.2749	5.3522	4.6482	3.9326	2.9428
	3	9.9654	8.3484	7.6470	6.7094	5.9852	5.2363	4.1662
5	2	8.7399	7.1287	6.4335	5.5106	4.8065	4.0907	3.0996
	3	10.3470	8.7295	8.0277	7.0889	6.3631	5.6116	4.5344
	4	10.8575	9.2388	8.5359	7.5941	6.8650	6.1075	5.0154
6	2	8.8814	7.2702	6.5748	5.6519	4.9476	4.2313	3.2389
	3	10.6707	9.0528	8.3507	7.4110	6.6840	5.9304	4.8478
	4	11.7680	10.1467	9.4413	8.4940	7.0841	6.9873	5.8671
	5	12.1732	10.5510	9.8447	8.8954	8.1559	7.3823	6.2525
7	2	5.1320	4.3116	3.9530	3.4700	3.0935	4.3566	3.3629
	3	10.9508	9.3326	8.6301	7.6898	6.9619	6.2066	5.1200
	4	12.2021	10.5802	9.8742	8.9255	8.1867	7.4142	6.2868
	5	12.5383	10.9158	10.2092	9.2592	8.5187	7.7434	6.6095
	6	13.3847	11.7599	11.0511	10.0962	9.3495	8.5646	7.4087

TABLE 4

Power of Test 2 with SRSS data from the exponential distribution ($\alpha = 0.05$)

n	l	θ 1.10	1.25	1.50	2.00	3.00	5.00	10.0	25.0
3	2	0.0743	0.1186	0.2063	0.3922	0.6702	0.8943	0.9862	0.9994
4	2	0.0754	0.1226	0.2175	0.4204	0.7151	0.9269	0.9939	0.9999
	3	0.0830	0.1488	0.2871	0.5665	0.8708	0.9871	0.9998	1.0000
5	2	0.0650	0.1263	0.2278	0.4458	0.7524	0.9789	0.9973	1.0000
	3	0.0855	0.1581	0.3130	0.6187	0.9120	0.9948	1.0000	1.0000
	4	0.0887	0.1702	0.3463	0.6783	0.9461	0.9983	1.0000	1.0000
6	2	0.0774	0.1296	0.2372	0.4688	0.7835	0.9638	0.9988	1.0000
	3	0.0877	0.1663	0.3361	0.6624	0.9393	0.9979	1.0000	1.0000
	4	0.0904	0.1766	0.3645	0.7107	0.9616	0.9993	1.0000	1.0000
	5	0.0973	0.2032	0.4342	0.8062	0.9875	1.0000	1.0000	1.0000
7	2	0.0825	0.1464	0.2787	0.5448	0.8474	0.9802	.9995	1.0000
	3	0.0896	0.1737	0.3569	0.6993	0.9576	0.9991	1.0000	1.0000
	4	0.0976	0.2046	0.4386	0.8126	0.9890	1.0000	1.0000	1.0000
	5	0.0999	0.2142	0.4634	0.8411	0.9932	1.0000	1.0000	1.0000
	6	0.1057	0.2375	0.5210	0.8939	0.9977	1.0000	1.0000	1.0000

3.3. *Test 3 for Scale Parameter of an Exponential Distribution*

A two sided Test 3 can be obtained for testing the hypothesis

$$\begin{aligned} H_0 &: \quad \theta = \theta_0 \\ H_a &: \quad \theta \neq \theta_0 \end{aligned} \tag{18}$$

where the sample s is drawn by the SRSS method from an exponential distribution following section 2. Test 3 with size α for testing the hypothesis (18) is given by

$$\phi_3(x)=\begin{cases}0 & if\ K_L<\sum_{j=1}^{m}\sum_{i=1}^{l}Y_{ij}<K_U\\ 1 & Otherwise\end{cases}$$

The power function and the size of the test can be defined by

$$\beta_{\phi_{m3}}(\theta)=1-P_\theta\left(K_L<\sum_{j=1}^{m}\sum_{i=1}^{l}Y_{ij}<K_U\right)$$
$$=1-\int_{K_L}^{K_U}k_{*\theta}(w_l)dw_l$$

and $\alpha=\beta_{\phi_{m3}}(1)$, respectively.

The values of K_L and K_U for different α values are calculated and tabulated for $l\leq n\leq 7$ and $m=1$ in Table 5. Also the power function of the test (19) is shown in Table 6 for fixed $\alpha=0.05$ for the same sets of n, l and m.

4. CONCLUSION

Looking at the values of the power functions of the three tests (Test 1, Test 2 and Test 3), the following two regular observations can be realised:

i. the power of the tests increases as the value of parameter moves away from the value under null hypothesis,
ii. the power of the tests increases as the sample size n increases.

Moreover, comparing the power of the Test 1, Test 2 and Test 2 with those of the same tests using SRS and RSS data (see Muttlak and Abu Dayyeh 1996), only the common combinations of sample sizes and values of parameters are taken into consideration), it can be concluded that Test 1, Test 2 and Test 3 using SRSS data give higher powers.

Finally, the practicing researchers will find the critical values supplied in this paper very much helpful for using the SRSS method with higher degree of confidence.

TABLE 5

Critical values for Test 3 with SRSS data from the exponential distribution

		α					
		0.001		0.01		0.025	
n	l	K_l	K_u	K_l	K_u	K_l	K_u
3	2	0.1736	9.1047	0.3306	6.8001	0.4346	5.8805
4	2	0.2573	9.2746	0.4428	6.9701	0.5594	6.0507
	3	0.6845	106598	1.0046	8.3484	1.1890	7.4200
5	2	0.3402	9.4332	0.5476	7.1287	0.6739	6.2092
	3	0.9078	11.0414	1.2647	8.7295	1.4654	7.8005
	4	1.1786	11.5520	1.5810	9.2388	1.8026	8.3082
6	2	0.4200	9.5747	0.6449	7.2702	0.7784	6.3506
	3	1.2132	11.3652	1.4988	9.0528	1.7113	8.1233
	4	1.6960	12.4631	2.1676	10.1467	2.4214	8.4940
	5	1.9547	12.8683	2.4531	10.5510	2.7198	9.6156
7	2	0.3068	5.4822	0.4673	4.3116	0.5614	3.8364
	3	1.3050	11.6452	1.7106	9.3326	1.9321	8.4028
	4	2.0009	12.8972	2.5026	10.5802	2.7686	9.6452
	5	2.2370	13.2335	2.7536	10.9158	3.0292	9.9799
	6	2.6110	14.0803	3.3350	11.7599	3.6510	10.8209

		α			
		0.05		0.10	
n	l	K_l	K_u	K_l	K_u
4	2	0.6752	5.3522	0.8260	4.6482
	3	1.3636	6.7094	1.5817	5.9852
5	2	0.7971	5.5106	0.9555	4.8065
	3	1.6528	7.0889	1.8845	6.3631
	4	2.0074	7.5941	2.2580	6.8650
6	2	0.9074	5.6519	1.0718	4.9476
	3	1.9082	7.4110	2.1498	6.6840
	4	2.6528	8.4940	2.9326	7.0841
	5	2.9617	8.8954	3.2530	8.1559
7	2	0.6515	3.4700	0.7647	3.0935
	3	2.1362	7.6898	2.3854	6.9619
	4	3.0094	8.9255	3.2994	8.1867
	5	3.2779	9.2592	3.5761	8.5187
	6	3.9186	0.0962	4.2393	9.3495

TABLE 6

Power of Test 3 with SRSS data from the exponential distribution ($\alpha = 0.05$)

n	l	θ							
		0.50	0.75	0.90	1.10	1.25	1.50	3.00	5.00
3	2	0.1678	0.0632	0.0486	0.0583	0.0814	0.1404	0.5761	0.8482
4	2	0.2074	0.0703	0.0505	0.0581	0.0824	0.1466	0.6210	0.8885
	3	0.3464	0.0930	0.0533	0.0604	0.0967	0.1974	0.8071	0.9769
5	2	0.2447	0.0770	0.0513	0.0579	0.0835	0.1527	0.6599	0.9175
	3	0.4213	0.1134	0.0780	0.1216	0.1967	0.3598	0.9282	0.9961
	4	0.5003	0.1219	0.0577	0.0618	0.1085	0.2424	0.9085	0.9963
6	2	0.2795	0.0833	0.0525	0.0578	0.0847	0.1584	0.6937	0.9384
	3	0.4865	0.1197	0.0575	0.0612	0.1059	0.2338	0.8977	0.9954
	4	0.6281	0.1507	0.0617	0.0638	0.1223	0.2913	0.9605	0.9995
	5	0.6834	0.1657	0.0638	0.0648	0.1292	0.3157	0.9750	1.0000
7	2	0.3054	0.0855	0.0517	0.0609	0.0966	0.1935	0.7810	0.9669
	3	0.5432	0.1321	0.0594	0.0616	0.1010	0.2498	0.9245	0.9979
	4	0.6964	0.1702	0.0645	0.0647	0.1299	0.3190	0.9773	0.9997
	5	0.7399	0.1846	0.0665	0.0656	0.1361	0.3406	0.9857	1.0000
	6	0.8187	0.2158	0.0707	0.0680	0.1517	0.3977	1.0000	1.0000

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RIASSUNTO

Test d'ipotesi per dati campionati con il metodo "selected ranked set"

In questo lavoro sono descritte alcune procedure per saggiare ipotesi sui parametri di scala delle distribuzioni uniforme ed esponenziale usando dati campionati con il metodo "selected ranked set" (SRSS). Usando l'integrazione numerica sono state determinate le regioni critiche e la funzione di potenza dei test e sono state predisposte le necessarie tavole.

SUMMARY

Test procedures with selected ranked set sampling

Some procedures for testing hypotheses about the scale parameters of the uniform and exponential distributions using selected ranked set sampling (SRSS) data are described in this paper. Using numerical integration the critical regions and the power function of the test procedures are computed and the necessary tables for the critical regions are supplied.