Jour. Ind. Soc. Ag. Statistics
Vol. XLII, No. 1 (1990), pp. 86-97

ESTIMATION OF CHANGE AND AVERAGE OF FREQUENCY DISTRIBUTION OVER TIME

LOKESH ARORA
University of Rajasthan, Jaipur

(Received : December, 1985)

SUMMARY

The estimation of change and average of frequency distributions over time under successive sampling approach has been attempted. In comparing some selected sampling designs for estimation of change and average of frequency distributions over time, it has been observed that cluster sampling design with PPS sampling can be adopted with greater advantages.

Keywords : Error measures, change and average of frequency distributions, successive sampling, matched and unmatched units.

Introduction

In developing countries, the social and economic changes being very rapid, the planners are mainly interested in knowing about the structure of the frequency distributions over time and space instead of studying changes in averages and ratios. Dandekar and Rath [2], Srinivasan and Bardhan [4] showed a considerable interest in estimating distribution of households by consumer expenditure in the context of studying poverty in India. Murthy [3] evaluated some selected sample designs for estimating frequency distributions through an empirical study. Arora and Singh [1] evaluated some selected sampling designs under successive sampling approach to study the structure of the population by estimating frequency distributions.

An attempt is made in the paper to evaluate some selected sampling designs under successive sampling approach for estimation of a change in the frequency distributions at two points of time and also for the estimation of average frequency distributions over a period.

Estimation of Change and Average of Frequency Distribution Over Time

Consider the estimation of change and average of frequency distributions over two points of time by the following selected sampling designs under successive sampling approach :

(i) Direct Sampling of ultimate units;
(ii) Cluster Sampling of ultimate units; and
(iii) Two-stage Sampling.

Under these sampling designs, an estimate of the change in proportion and the estimate of average proportion over two points of time, in hth class of the frequency distribution ($h = 1, 2, \ldots, k$), has been obtained and then efficiencies of the sampling designs compared with respect to the error measures $E(\alpha_1)$ and $E(\alpha_2)$, proposed by Murthy [3].

Let there be N clusters, and M_i ($i = 1, 2, \ldots, N$) be the size of ith cluster such that $\sum_{i=1}^{N} M_i = M$ (the total number of ultimate units in the population). Let M_0 be the total number of ultimate units in the sample and expressible as $n\bar{M}$, where n is the number of sample clusters and $\bar{M} = \frac{M}{N}$.

The estimates of change and average in proportions over two points of time, in hth class of the frequency distribution, under the considered sampling design along with their respective error measures are discussed as follows.

(i) *Direct Sampling of Ultimate Units*

Sampling Scheme : Select a sample of m_0 ultimate units by SRSWOR from the M ultimate units of the population at first occasion. Obtain the frequency distribution in the desired K classes on the basis of the sample Retain a sub-sample of $m_{0\mu}$ ($0 \leqslant \mu \leqslant 1$) units by SRSWOR from m_0 and supplement it with ($m_0 - m\mu$) units selected from ($M - m_0$) units of the population by SRSWOR at second occasion. Obtain the frequency distribution in the desired K classes on the basis of matched sample, unmatched sample, and overall for both first and second occasions.

The estimate of the change in proportion over two points of time, in hth class of the frequency distributions is given by

$$\hat{P}^h_d = \frac{\mu (\sigma_1^{h2} + \sigma_2^{h2})}{(\sigma_1^{h2} + \sigma_1^{h2} - 2 \lambda \sigma_{12}^h)} (P^h_{2\mu} - P^h_{1\mu})$$

$$+ \frac{\lambda (\sigma_1^{h2} + \sigma_2^{h2} - 2 \sigma_{12}^h)}{(\sigma_1^{h2} + \sigma_2^{h2} - 2 \lambda \sigma_{12}^h)} (P^h_{2\lambda} - P^h_{1\lambda}) \quad (1)$$

The estimate of the average proportion over two points of time, in hth class of the frequency distribution ($h = 1, 2, \ldots, k$) is given by

$$\hat{P}h_a = \frac{\mu (\sigma_1^{h2} + \sigma_2^{h2})}{2 (\sigma_1^{h2} + \sigma_2^{h2} + 2\lambda \sigma_{12}^h)} (P^h_{1\mu} + P^h_{2\mu})$$

$$+ \frac{\lambda (\sigma_1^{h2} + \sigma_2^{h2} + 2 \sigma_{12}^h)}{2 \sigma_1^{h2} + \sigma_2^{h2} + 2 \lambda \sigma_{12}^h)} (P^h_{1\lambda} + P^h_{2\lambda}) \quad (2)$$

where

$P^h_{1\lambda}$ = the sample proportion of the unmatched units, in hth class of the frequency distribution at first occasion.

$= \dfrac{U_1^h}{m_0 \lambda}$, U_1^h being the number of unmatched sample units in hth class at first occasion.

$P^h_{2\lambda}$ = the sample proportion of the unmatched units in hth class at second occasion.

$= \dfrac{U_2^h}{m_0 \lambda}$, U_2^h being the number of unmatched sample units in hth class at second occasion.

$P^h_{1\mu}$ = the sample proportion of the matched units in hth class at first occasion.

$= \dfrac{m_1^h}{m_{0\mu}}$, m_1^h being the number of matched sample units in hth class at first occasion.

$P_{2\mu}^h$ = the sample proportion of the matched units in hth class at second occasion

$= \dfrac{m_2^h}{m_{0\mu}}$, m_1^h being the number of matched sample units in hth class at second occasion.

The variance of the estimate of the change in proportion over two points of time. in hth class of the frequency distribution is given by

$$V(\hat{P}_d^h = \frac{(\sigma_1^{h2} + \sigma_2^{h2})\ (\sigma_1^{h2} + \sigma_2^{h2} - 2\,\sigma_{12}^h)}{m_0\,(\sigma_1^{h2} + \sigma_2^{h2} - 2\,\lambda\,\sigma_{12}^h)} \tag{3}$$

The variance of the estimate of average proportion over two points of time, in hth class of the frequency distribution is given by

$$V(\hat{P}_a^h) = \frac{(\sigma_1^{h2} + \sigma_2^{h2})\ (\sigma_1^{h2} + \sigma_2^{h2} - 2\,\sigma_{12}^h)}{4m_0\,(\sigma_1^{h2} + \sigma_2^{h2} + 2\,\lambda\,\sigma_{12}^h)} \tag{4}$$

where σ_1^{h2} and σ_2^{h2} arre the population variances of the ultimate units in hth class at first and second occasion respectively, and σ_{12} is the population covariance between the units lying in hth class at both the occasions.

Here $\sigma_1^{h2} = P_1^h\,(1 - P_1^h)$; $\sigma_2^{h2} = P_2^h\,(1 - P_2^h)$

and $\sigma_{12}^h = (P_{12}^h - P_{12}^h\,P_2^h)$,

where

$P_1^h = \dfrac{M_1^h}{M}$ and $P_2^h = \dfrac{M_2^h}{M}$; M_1^h and M_2^h being the number of ultimate units in hth class at first and second occassions respectively, and P_1^{h2} $= \dfrac{M_{12}^h}{M}$, M_{12}^h being the number of ultimate units lying in hth class at both the occasions.

For measuring error, define on the lines of Murthy [3]

$$\alpha_1 = \sum_{h}^{K} (\hat{P}^h - P^h)^2$$

$$\alpha_2 = \sum_{h} \frac{(\hat{P}^h - P^h)^2}{P^h}$$

The error measures $E(\alpha_1)$ and $E(\alpha_2)$ for estimating cnange in frequency distribution over two points of time. and for estimating average frequency distributions over a period can easily be obtained.

(ii) *Cluster Sampling of Ultimate Units*

Sampling Scheme : Select n clusters by PPSWR from N clusters at first occasion, retain a sub-sample of $n_{\mu c}$ $(0 <_{\mu c} \leqslant 1)$ clusters from the n clusters by SRSWOR and supplement it with $(n - n_{\mu c})$ clusters selected from $(N - n)$ clusters by PPSWR at second occasion. Obtain the frequency distribution in the desired K classes on the basis of the ultimate units in the clusters selected at both the occasions.

The estimates of change and average in porportions, over two points of time, in hth class of the frequency distribution $(h = 1, 2, \ldots, k)$ are :

$$\hat{P}^h_{dc} = \frac{\mu c\,(\sigma^{h2}_{1c} + \sigma^{h2}_{2c})}{(\sigma^{h2}_{1c} + \sigma^{h2}_{2c} - 2\lambda_c\,\sigma^h_{12c})}\,(P^h_{2\mu c} - P^h_{1\mu c})$$

$$+ \frac{\lambda c\,(\sigma^{h2}_{1c} + \sigma^{h}_{2c} - 2\sigma^h_{12c})}{(\sigma^{h2}_{1c} + \sigma^{h2}_{2c} - 2\,\lambda c\,\sigma^h_{12c})}\,(P^h_{2\lambda c} - P^h_{1\lambda c}) \qquad (5)$$

and

$$\hat{P}^h_{ac} = \frac{\mu c\,(\sigma^{h_2}_{1c} + \sigma^{h2}_{2c})}{2\,(\sigma^{h2}_{1c} + \sigma^{h2}_{2c} + 2\,\lambda c\,\sigma^h_{12c})}\,(P^h_{2\mu c} + P^h_{1\mu c})$$

$$+ \frac{\lambda c\,(\sigma^{h2}_{1c} + \sigma^{h2}_{2c} + 2\,\sigma^h_{12c})}{2\,(\sigma^{h2}_{1c} + \sigma^{h2}_{2c} + 2\lambda_c\,\sigma^h_{12c})}\,(P^h_2\,\lambda c + P^h_2\,\lambda c) \qquad (6)$$

where $P^h_{1\lambda_c}$ = the estimate of the proportion of ultimate units of the unmatched clusters, at first occasion in hth class $= \frac{1}{n\lambda_c} \sum_{i}^{n\lambda_c} \frac{M^h_{1i}}{P_i M}$,

M^h_{1i} being the number of ultimate units of ith unmatched clusters, at first occasion, in hth class and P_i, the probability of selection of ith cluster.

Similarly for $P^h_{2\lambda_c}$ for unmatched clusters at second occasion, $P^h_{1\mu_c}$ and $P^h_{2\mu_c}$ for matched clusters at first and second occasions.

The variance of the estimates $\hat{P}^h_{dc}$ and $\hat{P}^h_{ac}$ are :

$$V(\hat{P}^h_{dc}) = \frac{(\sigma^{h2}_{1c} + \sigma^{42}_{2c})(\sigma^{h2}_{1c} + \sigma^{h2}_{2c} - 2\,\sigma^h_{12c})}{n(\sigma^{h2}_{1c} + \sigma^{h2}_{2c} - 2\lambda_c\,\sigma^h_{12c})} \tag{7}$$

and

$$V(\hat{P}^h_{dc}) = \frac{(\sigma^{h2}_{1c} + \sigma^{h2}_{2c})(\sigma^{h2}_{1c} + \sigma^{h2}_{2c} + 1\,\sigma^h_{12c})}{4n(\sigma^{h2}_{1c} + \sigma^{h2}_{2c} + 2\lambda_c\,\sigma^h_{12c})} \tag{8}$$

Here

$$\sigma^{h2}_{1c} = \left[\sum_{i}^{N} \left(\frac{M_i}{M}\right)^2 \frac{(P^h_{1e})^2}{P_i} - (P^h_1)^2\right]$$

$$\sigma^{h2}_{2c} = \left[\sum_{i}^{N} \left(\frac{M_i}{M}\right)^2 \frac{(P^h_{2i})^2}{P_i} - (P^h_2)^2\right]$$

and

$$\sigma^h_{12c} = \left[\sum_{i}^{N} \left(\frac{M_i}{M}\right)^2 \frac{P^h_{1i}\,P^h_{2i}}{P_i} - P^h_1\,P^h_2\right]$$

The error measures $E(\alpha_1)$ and $E(\alpha_2)$ can be obtained for estimating change in and average of frequency distribution over two points of time.

(iii) *Two-Stage Sampling*

Sampling Scheme : Select a sample of n primary stage units (p.s.u.) ftom N p.s.u's by PPSWR at first occasion. Retain a sub-sample of size $n_{\mu t}$ $(0 \leqslant \mu_t \leqslant 1)$ from n p.s.u's by SRSWOR and supplement it with $(N - n_{\mu t})$ p.s.u's selected by PPSWR from $(N - n)$ p.s.u's at the second occasion. Then select a sub-sample of second stage units (s.s.u's) of size m from each of the selected cluster at both the occasions. Find the freqquency distribution of s.s.u's of the matched and unmatched clusters at both the occasions in the desired K classes of the frequency distribution.

The estimates of change and average proportions, over two points, in hth class of the frequency distribution $(h = 1, 2, \ldots, k)$ are :

$$\hat{P}^h_{dt} = \frac{\mu_t \, (\sigma^{h2}_{1t} + \sigma^{h2}_{2t})}{(\sigma^h_{1t} + \sigma^{h2}_{2t} - 2\lambda_t \, \sigma^h_{12t})} (P^h_{2\mu t} - P^h_{1\mu t})$$

$$+ \frac{\lambda_t \, (\sigma^{h2}_{1t} + \sigma^{h2}_{2t} - 2 \, \sigma^h_{12t})}{(\sigma^{h2}_{1t} + \sigma^{h2}_{2t} - 2\lambda_t \, \sigma^h_{12t})} \, (P^h_{2\lambda t} - P^h_{1\lambda t}) \qquad (9$$

and

$$\hat{P}^h_{at} = \frac{\mu_t \, (\sigma^{h4}_{1t} + \sigma^{h2}_{2t})}{2 \, (\sigma^{h2}_{1t} + \sigma^{h2}_{2t} + 2\lambda_o \; \sigma^h_{12t})} \; (P^h_{2\mu t} + P^h_{1\mu t})$$

$$+ \frac{\lambda_t \, (\sigma^{h2}_{1t} + \sigma^{h2}_{2t} + 2 \, \sigma^h_{12t})}{2 \, \sigma^{h2}_{1t} + \sigma^{a2}_{2t} + 2\lambda_t \; \sigma^h_{12t})} \; (P^h_{2\lambda t} + P^h_{1\lambda t}) \qquad (10)$$

where

$P^h_{1\lambda t}$ = the estimate of the proportion of ultimate units of the unmatched p s u's at first occasion in hth class

$$= \frac{1}{n_{\lambda t}} \sum_{i}^{n_{\lambda t}} \frac{M_i}{M} \frac{P^h_{1i}}{P_i}, \text{ where } P^h_{1i} = \frac{U^h_{1i}}{U_{1i}},$$

U_{1i} being the number of ssu's selected from ith unmatched psu. at first occasion and U^h_{1i}, the number of selected ssu's from the ith unmatched psu's at first occasion in hth class,

Similarly, $P^h_{2\lambda t}$ for the second occasion in the case of unmatched case $P^h_{1\mu t}$ and $P^h_{2\mu t}$ for marched case at first and second occasions.

The variances of the estimates $\hat{P}^a_{dt}$ and $\hat{P}^h_{at}$ are

$$V(\hat{P}^h_{dt}) = \frac{(\sigma^{h2}_{1t} + \sigma^{h2}_{2t})(\sigma^{h2}_{1t} + \sigma^{h2}_{2t} - 2\,\sigma^h_{12t})}{n(\sigma^{h2}_{1t} + \sigma^{h2}_{2t} - 2\lambda_t\,\sigma^h_{12t})} \tag{11}$$

and

$$V(\hat{P}^h_{at}) = \frac{(\sigma^{h2}_{1t} + \sigma^{h2}_{1t})(\sigma^{h2}_{1t} + \sigma^{h2}_{2t} + \sigma^h_{12t})}{4\,n(\sigma^{h2}_{1t} + \sigma^{h2}_{2t} + 2\lambda_t\,\sigma^h_{12t})} \tag{12}$$

Here

$$\sigma_{1t}{}^2 = \left[\sum_i^N \left(\frac{M_i}{M}\right)^2 \frac{(P^h_{1i})}{P_i} - (P^h_1)^2\right]$$

$$+\left[\sum_i^N \left(\frac{M_i}{M}\right)^2 \frac{(M_i - m)\,P^h_{1i}\,(1 - P^h_{1i})}{P_i\,(M_i - 1)\,m}\right]$$

$$\sigma^{h2}_{2t} = \left[\sum_i^N \left(\frac{M_i}{M}\right)^2 \frac{(P^h_{2i})}{P_i} - (P^h_2)^2\right]$$

$$+\left[\sum_i^N \left(\frac{M_i}{M}\right)^2 \frac{(M_i - m)\,P^h_{2i}\,(1 - P^h_{2i})}{P_i\,(M_i - 1)\,m}\right]$$

and

$$\sigma^h_{12t} = \left[\sum_i^N \left(\frac{M_i}{M}\right)^2 \frac{(P^h_{1i}\,P^h_{2i})}{P_i} - P^h_1\,P^h_2\right]$$

$$+\left[\sum_i^N \left(\frac{M_i}{M}\right)^2 \frac{(M_i - m)\,(P^h_{12i} - P^h_{1i}\,P^h_{2i})}{P_i\,(M_i - 1)\,m}\right]$$

The error measures $E(\alpha_1)$ and $E(\alpha_2)$ for estimating change in and the average of the frequency distribution over two points of time can be workcd out.

It may be noted that the estimates of change and average of proportions contain unknown parameters which may, however, be estimated by the sample values. Further the estimate of the variance and also the error measures can also be obtained by substituting the sample estimates for different components appearing in the expressions.

Some empirical studies

For estimating change and average of frequency distributions over two points of time, the two error measures $E(\alpha_1)$ and $E(\alpha_2)$, in case of the sampling designs, considered here are in a complicated form, therefore, it is difficult to compare the sampling designs theoretically. Hence, an attempt has been made for comparison, though this approach may not lead to general conclusions applicable universally.

For the comparison of different sampling designs, the following two sets of data were used :

(a) Data relating to area under bajra for 36 villages of Delhi for the years 1976-77 and 1977-78, collected under High Yielding Variety Survey Programme at Indian Agricultural Statistics Research Institute (IASRI).

(b) Data relating to area under wheat for 36 villages of Delhi for the years 1976-77 and 197;-78, collected under High Yielding Variety Survey at IASRI.

Different aspects of the error measures $E(\alpha_1)$ and $E(\alpha_2)$ of the estimate of the change in and the average of proportions, over two occasions, in hth class of the frequency distribution ($h = 1, 2, \ldots, k$) are discussed.

Considering the estimates of the change in proportions, over two occasions it is observed that the error measures decrease with the increase in proportion of matching. Thus, by increasing the proportion of matching, the efficiency of the sampling design can be increased considerably. It is also seen that the values of λ for which the error measures are minimum, remain the same for entire range of the sample size considered. A consistent trend has been observed for all the three sampling designs and also for both the populations.

It is important to mention that the error measure under cluster sampling for E.P.S. is less than the respective values of P.P.S. This may be due to the fact that P_1^h, P_2^h and $(P_1^h + P_2^h)/2$ are expected to be proportional to the auxiliary variable, used for selection, whereas $| P_2^h - P_1^h |$ may not. However, this difference in the values of the error measures for E.P.S. and P.P.S. is not considerable especially for large samples. From the values of the error measures of the estimate of average proportion, over two occasions, it is observed that the error measures increase with the increase in proportion of matching (μ). The value of λ for which the error measures are minimum remains the same for entire range of the sample size considered. This trend has been observed in all the three sampling designs and for both the populations.

As expected, P.P.S. is more efficient than E.P.S. under cluster sampling as well as under two-stage sampling, for both the populations in this case.

Further to have a clear picture of the efficiencies of the sampling designs, under different conditions, the values of the two error measures $E(\alpha_1)$ and $E(\alpha_2)$, for all the three sampling designs, are presented for different sample sizes corresponding to that value of λ which gives the minimum error measures in the entire range considered.

It can be seen from Tables 1 and 2 that there is a gain in efficiency using P.P.S. sampling over E.P.S. for two-stage sampling whereas for culster sampling the use of P.P.S. sampling results in a loss in efficiency-

TABLE 1 – VALUES OF THE ERROR MEASURES $E(\alpha_1)$ and $E(\alpha_2)$ FOR ESTIMATING CHANGE—POPULATION A

S. No.	*Direct Sampling*		*Cluster Sampling*				*Two-Stage Sampling*			
	m_0	$E(\alpha)$	n	$\overline{M}$	*E. P. S.*	*P. P. S.*	n	m	*E. P. S.*	*P. P. S.*
$E(\alpha_1)$										
1	30	.0293	3	10	.0450	.0461	5	6	.0772	.0720
2	90	.0098	9	10	.0150	.0154	15	6	.0257	.0240
3	150	.0059	15	10	.0090	.0092	25	6	.0154	.0144
$E(\alpha_2)$										
1	30	.1730	3	10	.4693	.4734	5	6	.7556	.7029
2	90	.0577	9	10	.1564	.1578	15	6	.2519	.2343
3	150	.0346	15	10	.0939	.0947	25	6	.1511	.1406

TABLE 2—VALUES OF THE ERROR MEASURES $E(\alpha_1)$ AND $E(\alpha_2)$ FOR ESTIMATING CHANGE—POPULATION B

S. No.	*Direct Sampling*		*Cluster Sampling*				*Two-Stage Sampling*			
	m_0	$E(\alpha_1)$	*n*	$\overline{M}$	*E. P.*	*P. P. S*	*n*	*m*	*E. P.*	*P. P. S.*
$E(\alpha_1)$										
1	30	.0152	3	10	.0158	.0165	5	6	.0647	.0582
2	90	.0051	9	10	.0053	.0055	15	6	.0216	.0194
3	150	.0030	15	10	.0032	.0033	25	6	.0129	.0116
$E(\alpha_2)$										
1	30	.6966	3	10	.5372	.5558	5	6	1.7900	1.6188
2	90	.2322	9	10	.1791	.1853	15	6	.5967	.5396
3	150	.1393	15	10	.1074	.1112	25	6	.3580	.3238

over the use of E.P.S. But this loss in efficiency is not considerable.

From Tables 3 and 4, it has been observed that there is a gain in efficiency using P.P.S. sampling over E.P.S. for both the cluster sampling as well as two-stage sampling.

It is well known that cluster sampling and two-stage sampling are potentially better than the direct sampling of ultimate units when cost

TABLE 3—VALUES OF THE ERROR MEASURES $E(\alpha_1)$ AND $E(\alpha_2)$ FOR ESTIMATING AVERAGE—POPULATION A

S. No.	*Direct Sampling*		*Cluster Sampling*				*Two-stage Sampling*			
	m_0	*Error measure*	*n*	$\overline{M}$	*E. P.*	*P. P. S.*	*n*	*m*	*E. P.*	*P. P. S.*
$E(\alpha_1)$										
1	30	.0107	3	10	.0299	.0258	5	6	.0302	.0263
2	90	.0036	9	10	.0100	.0086	15	6	.0101	.0088
3	150	.0021	15	10	.0060	.0052	25	6	.0060	.0053
$E(\alpha_2)$										
1	30	.0111	3	10	.0288	.0250	5	6	.0303	.0265
2	90	.0037	9	10	.0096	.0083	15	6	.0101	.0088
3	150	.0022	15	10	.0058	.0050	25	6	.0061	.0053

TABLE 4—VALUES OF THE ERROR MEASURES $E(\alpha_1)$ AND $E(\alpha_2)$ FOR ESTIMATING AVERAGE—POPULATION B

S. No.	*Direct Sampling*		*Cluster Sampling*				*Two-stage Sampling*			
	m_0	*Error measure*	n	$\overline{M}$	*E. P.*	*P. P. S.*	n	m	*E. P.*	*P. P. S.*
$E(\alpha_1)$										
1	30	.0109	3	10	.0243	.0207	5	6	.0279	.0241
2	90	.0036	9	10	.0081	.0069	15	6	.0093	.0080
3	150	.0022	15	10	.0049	.0041	25	6	.0056	.0048
$E(\alpha_2)$										
1	30	.0111	3	10	.0234	.0202	5	6	.0281	.0245
2	90	.0037	9	10	.0078	.0067	15	6	.0094	.0082
3	150	.0022	15	10	.0047	.0040	25	6	.0056	.0049

aspect and operational convenience are the main considerations. Thus, keeping in view all the factors, such as, cost aspect, operational convenience and the magnitude of error measures in estimating the average and change of frequency distributions simultaneously over two points of time, cluster sampling with P.P.S. sampling can be adopted with greater advantages.

REFERENCES

[1] Arora, Lokesh and Singh, D. (1981) : Estimation of frequency distributions for the current occasion under sucessive sampling approach for some selected sampling designs, *Journal. Indian Soc. Agri. Stat*, XXIII (1) : 60-80.

[2] Dandekar, V. M. and Rath, N. (1970) : *Poverty in India*. Indian School of Political Economy, Pune.

[3] Murthy, M. N. (1977) : Presented a paper on "Use of empirical studies in evaluating sample designs for estimating frequency distribution", at the 41st Session of the International Statistical Institute, New Delhi (5-15 December, 1977).

[4] Srinivasan, T. N. and Bardhan, P. K. (1974) : *Poverty and Income Distribution in India*, Statistical Publishing Society, Calcutta.