Some New Estimators of Population Mean Using PPS Sampling

Anita¹, Shashi Bahl²

¹Research Scholar, Department of Statistics, M.D.U. Rohtak (Haryana) India
²Professor (Retd.), Department of Statistics, M.D.U. Rohtak (Haryana) India

Abstract: In this study we consider some ratio and product type estimators where we calculate bias and mean square error of these estimators. These estimators are compared with usual ratio and product estimators & with mean-per unit. An empirical illustration is also included to justify the practical utility of the proposed estimators.

Keywords: Ratio estimators, product estimators, probability proportional to size sampling Bias, Mean square error

1. Introduction

The method of PPS selection was familiar to Mahalanobis even as early as 1937. About seventy years ago, Hansen and Hurwitz (1943) introduced the method of selecting units of a finite population with probability proportional to a given size measure (PPS) and demonstrated its efficiency over simple random sampling method. Unequal probability sampling There are situations in which it is desirable to have unequal probability of selecting elements into the sample. The estimators based on unequal probability sampling and the ratio estimators are generally more efficient than the simple estimator based on equal probability sampling when the regression line of y on x passes through the origin.

Notations

Let $y_i, x_{i1}$ and $x_{i2}$ be two values of characters y under study and values of the two auxiliary characters $x_1$ and $x_2$ for the $i^{th}$ unit in the population $(i=1,2,..,N)$ of the population of size N. Let a sample of size n be drawn with psps sampling (based on $x_1$) and Y, X1, X2 be population total of y, x1, x2 respectively

$u_i = \frac{y_i}{N} \frac{x_{i1}}{n} = \frac{x_{i1}}{x_1}$

$\bar{u}_n = \frac{1}{n} \sum_{i=1}^{n} u_i = \bar{y}_{PPS}$

$\bar{v}_n = \frac{1}{n} \sum_{i=1}^{n} v_i = \bar{x}_{PPS}$

$\sigma_u^2 = \frac{\sum_{i=1}^{n} (u_i - \bar{u})^2}{n}$, $\sigma_v^2 = \frac{\sum_{i=1}^{n} (v_i - \bar{v})^2}{n}$

$\rho_{uv} = \frac{\sum_{i=1}^{n} (u_i - \bar{u})(v_i - \bar{v})}{\sigma_u \sigma_v}$

$\bar{y}_R = \frac{\sum_{i=1}^{n} y_i x_{i2}}{\sum_{i=1}^{n} x_{i2}}$

$\bar{y}_p = \frac{\sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} x_{i2}}$

2. Proposed Estimators

$\bar{y}_{RPT} = \bar{y}_{PPS} = \frac{\bar{y}_{PPS} - \bar{x}_{PPS}}{\bar{x}_{PPS}} + 1$ --- --- (5)

$\bar{y}_{RPT} = \bar{y}_{PPS} = \frac{\bar{y}_{PPS} - \bar{x}_{PPS}}{\bar{x}_{PPS}} + 1$ --- --- (2)

$\bar{y}_{RPT} = \bar{y}_{PPS} = \frac{\bar{y}_{PPS} - \bar{x}_{PPS}}{\bar{x}_{PPS}} + 1$ --- --- (3)

$\bar{y}_{RPT} = \bar{y}_{PPS} = \frac{\bar{y}_{PPS} - \bar{x}_{PPS}}{\bar{x}_{PPS}} + 1$ --- --- (4)

3. Bias and MSE of the proposed Estimators

<table>
<thead>
<tr>
<th>Bias</th>
<th>MSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B(\bar{y}_{RPT})$</td>
<td>$M(\bar{y}^2 C_u^2 + C_v^2 - 2\bar{y} \rho_u C_u C_v)$</td>
</tr>
<tr>
<td>$B(\bar{y}_{RPT}) - C_v^2$</td>
<td>$M(\bar{y}^2 C_u^2 + C_v^2 + 2\bar{y} \rho_u C_u C_v)$</td>
</tr>
<tr>
<td>$B(\bar{y}<em>{RPT}) (1+\bar{y})^2 C_v^2 - \bar{y}</em>{RPT} C_u C_v$</td>
<td>$M(\bar{y}^2 C_u^2 + (1+\bar{y})^2 C_v^2 - 2\bar{y}(1+\bar{y}) \rho_u C_u C_v)$</td>
</tr>
<tr>
<td>$B(\bar{y}_{RPT}) \bar{y} \rho_u C_u C_v$</td>
<td>$M(\bar{y}^2 C_u^2 + (1+\bar{y})^2 C_v^2 + 2\bar{y}(1+\bar{y}) \rho_u C_u C_v)$</td>
</tr>
<tr>
<td>$B(\bar{y}<em>{RPT}) (\bar{y} - 1)^2 C_v^2 - \bar{y}</em>{RPT} C_u C_v$</td>
<td>$M(\bar{y}^2 C_u^2 + (\bar{y} - 1)^2 C_v^2 + 2\bar{y}(\bar{y} - 1) \rho_u C_u C_v)$</td>
</tr>
<tr>
<td>$B(\bar{y}<em>{RPT}) (\bar{y} - 1)^2 C_v^2 - \bar{y}</em>{RPT} C_u C_v$</td>
<td>$M(\bar{y}^2 C_u^2 + (\bar{y} - 1)^2 C_v^2 + 2\bar{y}(\bar{y} - 1) \rho_u C_u C_v)$</td>
</tr>
</tbody>
</table>

4. Comparison of the Proposed Estimators

4.11 MSE ($\bar{y}_{RPT}$) < MSE ($\bar{y}_R$)

$\bar{y}^2 C_u^2 + C_v^2 - 2\bar{y} \rho_u C_u C_v < \bar{y}^2[C_u^2 + C_v^2 - 2\rho_u C_u C_v]$

$(1 - \bar{y})^2 C_v^2 - 2\bar{y}(1 - \bar{y}) \rho_u C_u C_v < 0$

$(1 + \bar{y})C_v^2 - 2\bar{y} \rho_u C_u C_v < 0$

$\frac{1 + \bar{y}}{2\bar{y}} < \rho_u C_u C_v$

4.12 With Mean per unit

MSE ($\bar{y}_{RPT}$) < MSE ($\bar{y}$)

$\bar{y}^2 C_u^2 + C_v^2 - 2\bar{y} \rho_u C_u C_v < C_v^2$

$(\bar{y}^2 - 1)C_u^2 + C_v^2 - 2\rho_u C_u C_v < 0$

$(\bar{y}^2 - 1)C_u^2 + C_v^2 < 2\rho_u C_u C_v$

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4.41 \text{MSE} \left( \bar{Y}_{PR} \right) < \text{MSE} \left( \bar{Y} \right)

\begin{align*}
Y^2C_u^2 + \left(1+\bar{Y}\right)Y^2C_v^2 - 2\bar{Y}(1+\bar{Y})\rho_{uv}CuC_v < Y^2\left[C_u^2 + 2\rho_{uv}CuC_v\right] \\
\left(1-\bar{Y}^2\right)C_u^2 + 2\bar{Y}(1-\bar{Y})\rho_{uv}CuC_v < 0 \\
\left(1+\bar{Y}\right)C_v^2 < -2\bar{Y}\rho_{uv}CuC_v
\end{align*}

\begin{align*}
\frac{1+\bar{Y}}{2\bar{Y}} < \frac{C_v}{C_u}
\end{align*}

4.62 With Mean per unit

\text{MSE} \left( \bar{Y}_{RPT4} \right) < \text{MSE} \left( \bar{Y} \right)

\begin{align*}
\left(Y^2C_u^2 + \left(1-\bar{Y}\right)Y^2C_v^2 - 2\bar{Y}(\bar{Y} - 1)\rho_{uv}CuC_v\right) < C_u^2 \\
\left(\bar{Y}^2 - 1\right)C_u^2 + \left(1-\bar{Y}\right)Y^2C_v^2 < 2\bar{Y}(\bar{Y} - 1)\rho_{uv}CuC_v \\
\left(\bar{Y} + 1\right)C_u^2 + \left(1-\bar{Y}\right)C_v^2 < 2\bar{Y}\rho_{uv}CuC_v
\end{align*}

5. Empirical Study

To see the performance of the proposed estimators in comparison to other estimators, description of population data are given below:

\textbf{Population: [Source: Steel and Torrie (1960, p.282)]}

\(Y\) : Long of leaf burn in sec.,
\(X_1\) : Potassium Percentage
\(X_2\) : Clorine Percentage.

The required population parameters are:

\(Y\bar{=}0.6860, C_v\bar{=}0.4803, N\bar{=}30, n\bar{=}6

\rho_{xy1}\bar{=}0.1794, C_{x_1}\bar{=}0.2295, C_{x_2}\bar{=}0.7493, \rho_{x_1x_2}\bar{=}0.4074

\bar{X}_1\bar{=}4.6537, \rho_{yx2}\bar{=}0.4996 \bar{X}_2\bar{=}0.8077, g\bar{=}2

\text{MSE of proposed estimators}

1. M (\bar{Y}_{RT}) = 0.13409, 2.M (\bar{Y}_{PP}) = 0.18836 , 3. M (\bar{Y}_{RPT}) = 0.21252

4. M (\bar{Y}_{RPT3}) = 0.30401, 5.M (\bar{Y}_{RPT3}) = 0.10523 , 6. M (\bar{Y}_{RPT4}) = 0.12227

7. M (\bar{Y}_R) = 0.23478, 8.M (\bar{Y}_p) = 0.51077, 9.M (\bar{Y}) = 0.23068

Percentage Relative Efficiencies (PRE)

<table>
<thead>
<tr>
<th>Estimators</th>
<th>R.E over (\bar{y})</th>
<th>R.E over (\bar{y}_R)</th>
<th>R.E over (\bar{y}_P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\bar{y})</td>
<td>101.77</td>
<td>221.41</td>
<td></td>
</tr>
<tr>
<td>(\bar{y}_R)</td>
<td>98.25</td>
<td>217.55</td>
<td></td>
</tr>
<tr>
<td>(\bar{y}_P)</td>
<td>45.16</td>
<td>45.96</td>
<td></td>
</tr>
<tr>
<td>(\bar{y}_{RT})</td>
<td>171.97</td>
<td>175.09</td>
<td></td>
</tr>
<tr>
<td>(\bar{y}_{RPT})</td>
<td>122.46</td>
<td></td>
<td>271.16</td>
</tr>
<tr>
<td>(\bar{y}_{RPT3})</td>
<td>108.54</td>
<td>110.47</td>
<td></td>
</tr>
<tr>
<td>(\bar{y}_{RPT2})</td>
<td>75.87</td>
<td></td>
<td>168.01</td>
</tr>
<tr>
<td>(\bar{y}_{RPT4})</td>
<td>219.21</td>
<td></td>
<td>485.38</td>
</tr>
<tr>
<td>(\bar{y})</td>
<td>188.66</td>
<td>192.01</td>
<td></td>
</tr>
</tbody>
</table>

6. Conclusion

The proposed estimators are found to be better usual Mean per unit , ratio and product estimators.

References