Double Partitioned Ranked Set Sampling: An Efficient Estimation Technique

K.B. Panda¹, M. Samantaray²

¹,²Department of Statistics, Utkal University, Bhubaneswar, Odisha, India

Abstract: Following Ranked Set Sampling (RSS) due to McIntyre (1952), Takahasi and Wakimoto (1968), Dell and Clutter (1972) and the Median Ranked Set Sampling (MRSS) method by Muttlak (1997), a new sampling strategy has been proposed. While the newly proposed sampling design is called Double Partitioned Ranked Set Sampling (DPRSS), the estimator based thereon, besides being unbiased for the population mean, is found to be more efficient than the corresponding estimators in simple random sampling, ranked set sampling and median ranked set sampling. The theoretical findings have been supported by suitable numerical illustration.

Keywords: Simple Random Sampling, Ranked Set Sampling, Median Ranked Set Sampling, Double Ranked Set Sampling, Double Partitioned Ranked Set Sampling.

I. INTRODUCTION

McIntyre (1952) introduced a technique of sampling called Ranked Set Sampling (RSS) for estimating the mean of a finite population. This is possible where the sampling units in a survey can be more easily ranked than quantified. The estimator thus obtained comes out to be unbiased for population mean with a variance less than that of usual sample mean based on Simple Random Sampling of the same size. Muttalak (1997) proposed an estimator using Median Ranked Set Sampling (MRSS) with a view to increasing efficiency of the estimator and reducing errors in ranking. Muttalak (2003) proposed Quartile Ranked Set Sampling (QRSS) for estimating population mean is also applicable for reducing error as compared to RSS. Al-Saleh and Al-Kadiri (2000) suggested Double Ranked Set Sampling (DRSS) for estimating the population mean. According to them the ranking at second stage is easier than first stage.

II. SAMPLING METHODS

A. Ranked Set Sampling (RSS)

RSS procedure involves selection of m random samples with m units in each sample. The m units in each sample are ranked with respect to a variable of interest without actually measuring them. Then the smallest rank is measured from the first sample, the second smallest rank from second sample and the procedure is continued till the unit with highest rank is measured from the mth sample. The order of observations from the lowest to the highest in the m samples can be presented as

\[ x_{(11)} \quad x_{(12)} \quad \ldots \quad x_{(1m)} \]
\[ x_{(21)} \quad x_{(22)} \quad \ldots \quad x_{(2m)} \]
\[ x_{(m1)} \quad x_{(m2)} \quad \ldots \quad x_{(mm)} \]

The observations \( x_{(11)}, x_{(22)} \ldots x_{(mm)} \) are then accurately measured to form RSS data. If m is small, then the cycle may be repeated for r times so as to obtain a combined sample of size mr.

B. Median Ranked Set Sampling (MRSS)

MRSS procedure involves selection of m random samples each of size m units from population and ranked them within each sample. If sample size m is odd, then select lowest ranks from each of the first \((m-1)/2\) samples, the median from \((m+1)/2\)th sample and the highest ranks from each of the last \((m-1)/2\) sample. If sample size m is even, then select lowest rank from each of the first \(m/2\) samples and highest rank from each of the last \(m/2\) samples. If m is small, then the cycle may be repeated for r times to have a combined sample of size mr. The ranked units are then quantified.

C. Partitioned Ranked Set Sampling (PRSS)

According to PRSS procedure, select \(m^2\) units from the population and then divide them into m sets each of having size m. If sample size is odd, then select \((p(m+1))^{th}\) rank from first \((m-1)/2\) sets and \((q(m+1))^{th}\) rank from last \((m-1)/2\) sets, with median from...
Motivated by the above procedure, we arrive at each
which indicates
Now applying PRSSO method on each 25 sets, The
After ranking, the units within each subset may be taken as
Let m=5, then we have
F.
To understand the above procedure, let us consider the following two example.

Here, we have to remember that, the ranking should be done by visual inspection or by any economical procedure and actual quantification is done at final stage.

To understand the above procedure, let us consider the following two example.

For odd sample size, we have to apply DPRSSO method which may be described as follows. Let m=5, then we have to select random sample of 25 sets, each should contain 5 units. Let \( X_{j(i;m)}^{(n)} \) be the \( i \)th value \((i=1,2,....,5)\) out of the \( j \)th set \((1,2,......,25)\) at the \( n \)th stage.

After ranking, the units within each subset may be taken as
\[
X_1^{(0)} = \{X_0^{(0)}(1;5), X_0^{(0)}(2;5), \ldots, X_0^{(0)}(5;5)\},
\]
\[
X_2^{(0)} = \{X_0^{(0)}(2;5), X_0^{(0)}(2;5), \ldots, X_0^{(0)}(5;5)\},
\]
\[
X_{25}^{(0)} = \{X_0^{(0)}(25;5), X_0^{(0)}(25;5), \ldots, X_0^{(0)}(25;5)\}.
\]

Now applying PRSSO method on each 25 sets, The first partitioned value \( p(m+1) \) (for \( p=25\% \) ) = 25% \((5+1)\)= 1.5th observation, which indicates the first or lowest observation, i.e., we have to assume \( p(m+1) \) rank from each of first \( m(m-2)/2=10 \) sets. Similarly, the last partitioned value \( q(m+1) \) (for \( q=75\% \) ) = 75% \((5+1)\)= 4.5th observation indicates the fifth observation or largest rank from each of last 10 sets and median of each 5 sets containing 5 units will give middle 5 observations for next stage.

Using the above procedure, we arrive at
\[
X_{1(1;5)}^{(1)} = \min\left(X_1^{(0)}\right),
\]
\[
X_{10(1;5)}^{(1)} = \min\left(X_{10}^{(0)}\right).
\]
Let \(m=6\), Hence we have to select 6 variables. The above observations can be reorganised in the following 5 sets

\[
X_{11(m;5)}^{(i)} = \text{median}(X_{11}^{(0)})
\]

\[
X_{12(m;5)}^{(i)} = \text{median}(X_{12}^{(0)})
\]

\[
X_{15(m;5)}^{(i)} = \text{median}(X_{15}^{(0)})
\]

\[
X_{16(5;5)}^{(i)} = \text{max}(X_{16}^{(0)})
\]

\[
X_{17(5;5)}^{(i)} = \text{max}(X_{17}^{(0)})
\]

\[
X_{25(5;5)}^{(i)} = \text{max}(X_{25}^{(0)})
\]

Thus, the above observations can be reorganised in the following 5 sets

\[
X_1^{(1)} = \left\{X_1^{(1)}, X_2^{(1)}, \ldots, X_{16}^{(1)}, X_{17}^{(1)}, \ldots, X_{25}^{(1)}\right\}
\]

\[
X_2^{(1)} = \left\{X_2^{(1)}, X_3^{(1)}, \ldots, X_{11}^{(1)}, X_{16}^{(1)}, \ldots, X_{17}^{(1)}, X_{25}^{(1)}\right\}
\]

\[
X_3^{(1)} = \left\{X_3^{(1)}, X_4^{(1)}, \ldots, X_{12}^{(1)}, X_{17}^{(1)}, \ldots, X_{25}^{(1)}\right\}
\]

\[
X_4^{(1)} = \left\{X_4^{(1)}, X_5^{(1)}, \ldots, X_{13}^{(1)}, X_{20}^{(1)}\right\}
\]

\[
X_5^{(1)} = \left\{X_5^{(1)}, X_6^{(1)}, X_7^{(1)}\right\}
\]

Now, applying the same procedure once again to the above data, we get DPRSSO technique which will have \(p(m+1)\)th rank from \((m-1)/2=2\) sets and choose \(q(m+1)\)th rank from last 2 set and the median from middle set. Then DPRSSO partitioned sample is

\[
X_{1(1;5)}^{(2)} = \text{min}(X_1^{(1)})
\]

\[
X_{2(1;5)}^{(2)} = \text{min}(X_2^{(1)})
\]

\[
X_{3(1;5)}^{(2)} = \text{median}(X_3^{(1)})
\]

\[
X_{4(5;5)}^{(2)} = \text{max}(X_4^{(1)})
\]

and

\[
X_{5(5;5)}^{(2)} = \text{max}(X_5^{(1)})
\]

The sample observations thus obtained constitute a random sample, i.e., the observations are the realisation of 5 i.i.d. random variables. These 5 observation are to be measured.

Let \(m=6\). Hence we have to select 6 units in 36 sets, each have 6 units. Let us assume that, \(X_{j;6}^{(a)}\) be the \(i^{th}\) observation \((i=1,2,\ldots,6)\) out of the \(j^{th}\) set \((j=1,2,\ldots,36)\) at the \(n^{th}\) stage. After arranging, the units within each sets, we have

\[
X_1^{(0)} = \left\{X_{1;6}^{(0)}, X_{2;6}^{(0)}, \ldots, X_{6;6}^{(0)}\right\}
\]

\[
X_2^{(0)} = \left\{X_{2;6}^{(0)}, X_{3;6}^{(0)}, \ldots, X_{6;6}^{(0)}\right\}
\]

\[
X_{36}^{(0)} = \left\{X_{36;6}^{(0)}, X_{37;6}^{(0)}, \ldots, X_{6;6}^{(0)}\right\}
\]

Now, applying of PRSSE method on each of 36 sets.
The first partitioned values \((p(m+1))^{th}\) observation, i.e., the lowest rank from each of first \(m^2/2\) = 18 sets. The last partitioned value \(q(m+1))^{th}\) rank, i.e., largest rank from each of last \(m^2/2\) = 18 observations.

Using the above procedure, we have

\[ X_{1_{[1;5]}}^{(1)} = \min \left( X_{1}^{(0)} \right) \]
\[ X_{2_{[1;5]}}^{(1)} = \min \left( X_{2}^{(0)} \right) \]
\[ \vdots \]
\[ X_{18_{[1;6]}}^{(1)} = \min \left( X_{18}^{(0)} \right) \]
\[ X_{19_{[6;6]}}^{(1)} = \max \left( X_{19}^{(0)} \right) \]
\[ X_{20_{[6;6]}}^{(1)} = \max \left( X_{20}^{(0)} \right) \]
and \[ X_{36_{[6;6]}}^{(1)} = \max \left( X_{36}^{(0)} \right) \]

The obtained values can be rearranged in the following 5 sets

\[ X_1^{(1)} = \left\{ X_{1_{[1;6]}}, X_{2_{[1;6]}}, \ldots, X_{6_{[1;6]}} \right\} \]
\[ X_2^{(1)} = \left\{ X_{7_{[1;6]}}, X_{8_{[1;6]}}, \ldots, X_{12_{[1;6]}} \right\} \]
\[ X_3^{(1)} = \left\{ X_{13_{[1;6]}}, X_{14_{[1;6]}}, \ldots, X_{18_{[1;6]}} \right\} \]
\[ X_4^{(1)} = \left\{ X_{19_{[6;6]}}, X_{20_{[6;6]}}, \ldots, X_{24_{[6;6]}} \right\} \]
\[ X_5^{(1)} = \left\{ X_{25_{[6;6]}}, X_{26_{[6;6]}}, \ldots, X_{30_{[6;6]}} \right\} \]
\[ X_{6}^{(1)} = \left\{ X_{31_{[6;6]}}, X_{32_{[6;6]}}, \ldots, X_{36_{[6;6]}} \right\} \]

Now, applying the same procedure once again to the above data, we have \(p(m+1))^{th}\), i.e., smallest rank out of first \(m/2\) = 3 sets and \(q(m+1))^{th}\), i.e., highest observations from last 3 sets. Then

\[ X_{1_{[1;6]}}^{(2)} = \min \left( X_{1}^{(1)} \right) \]
\[ X_{2_{[1;6]}}^{(2)} = \min \left( X_{2}^{(1)} \right) \]
\[ X_{3_{[1;6]}}^{(2)} = \min \left( X_{3}^{(1)} \right) \]
\[ X_{4_{[6;6]}}^{(2)} = \max \left( X_{4}^{(1)} \right) \]
\[ X_{5_{[6;6]}}^{(2)} = \max \left( X_{5}^{(1)} \right) \]
\[ X_{6_{[6;6]}}^{(2)} = \max \left( X_{6}^{(1)} \right) \]

The sample observations thus obtained constitute a random sample, i.e., the observations are the realisation of 6 i.i.d. random variables. These 5 observation are to be measured.
### III. GENERAL SET UP AND SOME BASIC RESULTS:

Let $X_{11}$, $X_{12}$, ....,$X_{1m}$;
$X_{21}$, $X_{22}$, ....,$X_{2m}$;
$X_{m1}$, $X_{m2}$,...,$X_{m^2}$;
be $m^2$ independent random sets of size $m$.

Let us assume that, each variable $X_{ij}$ has common distribution function $\text{cdf} F(x)$ with probability density function $pdf$ $f(x)$ having mean $\mu$ and variance $\sigma^2$ respectively. Let $X_{i(1)}$, $X_{i(2)}$.....$X_{i(m)}$, where $(i = 1, 2.....m^2)$ be the ordered statistics of the $i^{th}$ sample $X_{11}$, $X_{12}$, .....$X_{1m}(i = 1.2 ....m^2)$

The SRS estimator of the population mean from a sample size $m$ is given by,

$$\bar{X}_{\text{SRS}} = \frac{1}{m} \sum_{i=1}^{m} X_i$$

with variance $\sigma^2/m$. \hspace{1cm} (3.1)

The estimator of the population mean for RSS of size $m$(McIntyre (1952)) is given by,

$$\bar{X}_{\text{RSS}} = \frac{1}{m} \sum_{i=1}^{m} X_{i(m)}$$

and $\text{Var}(\bar{X}_{\text{RSS}}) = \frac{1}{m^2} \sum_{i=1}^{m} \text{var}(X_{i(m)})$

$$= \frac{\sigma^2}{m} - \frac{1}{m^2} \sum_{i=1}^{m} (\mu_{i(m)} - \mu)^2$$ \hspace{1cm} (3.2)

since $\sum_{i=1}^{m} (\mu_{i(m)} - \mu)^2 \geq 0$, $\bar{X}_{\text{RSS}}$ is more efficient than $\bar{X}_{\text{SRS}}$ based on same number of measured observations.

The DRSS estimator of population mean from a sample of size $m$(Al-Saleh and Al-Omari (2002)) is given by

$$\bar{X}_{\text{DRSS}}^{(2)} = \frac{1}{m^2} \sum_{i=1}^{m} X_{i(2)}$$

and $\text{Var}(\bar{X}_{\text{DRSS}}^{(2)}) = \frac{1}{m^2} \sum_{i=1}^{m} \text{var}(X_{i(2)}) = \frac{1}{m} \left[ \sigma^2 - \frac{1}{m} \sum_{i=1}^{m} (\mu_{i(2)} - \mu)^2 \right]$ \hspace{1cm} (3.3)

where $\mu$ and $\sigma^2$ are the mean and the variance of the population respectively.

It is interest to have attention that theDRSS method is suggested by Al-Saleh and Al-Omari (2002) constitute by apply the usual RSS method on $m^2$ sets each of size $m$, which is difference from our work based on DPRSS technique where we apply PRSS method on $m^2$ sets each of size $m$.

To estimate the population mean using DPRSS method, suppose, at $K^{th}$ cycle, for $(K = 1, 2 .... r),$

A. For even sample size, let $X_{i(p(m+1)k)}^{(2)}$ be the first partitioned values for the $i$ sets$(i = 1, 2 ......l ; l = m/2)$ and $X_{j(q(m+1)k)}^{(2)}$ be the last partitioned value for the $j$ sets $(j = 1 + 1, .......m)$. Then the partitioned sample,

$[X_{1(p(m+1)k)}^{(2)}, X_{2(p(m+1)k)}^{(2)}, .......X_{m(p(m+1)k)}^{(2)}; X_{m/2+1(q(m+1)k)}^{(2)}, X_{m/2+2(q(m+1)k)}^{(2)}, .......X_{m(q(m+1)k)}^{(2)}]$, units are i.i.d, however, all units are mutually independent but not identically distributed. These measured units are DPRSSE(Double Partitioned Ranked Set Sampling even Size).

B. If the sample size is odd, let $X_{i(p(m+1)k)}^{(2)}$ be the first partitioned values of the $i$ sets$(i = 1, 2......h; h=(m-1)/2),$ wit
\( X^{(2)} \) \((m+1)/2\) is the median and \( X^{(2)}_{j(q(m+1)k)} \) be the last partitioned values for the sets ( \( j = h + 2, \ldots, m \)). Then the partitioned samples are

\[
\begin{align*}
X^{(2)}_{i(p(m+1)k)}; X^{(2)}_{2(p(m+1)k)}; \ldots; X^{(2)}_{h(p(m+1)k)}; X^{(2)}_{(h+1)(q(m+1)k)}; X^{(2)}_{(h+2)(q(m+1)k)}; \ldots; X^{(2)}_{m(q(m+1)k)}
\end{align*}
\]

units are i.i.d., however, all units are mutually independent but not identically distributed. These measured units are DPRSS (Double Partitioned Ranked Set Sampling odd Size).

The estimators of the population mean using DPRSS for sample size even and odd respectively are given by,

\[
\begin{align*}
\bar{X}^{(2)}_{DPRSS} &= \frac{1}{m} \left( \sum_{i=1}^{l} X^{(2)}_{i(p(m+1)k)} + \sum_{j=l+1}^{m} X^{(2)}_{j(q(m+1)m)} \right), \quad \text{where} \quad l = m/2 \\
\bar{X}^{(2)}_{DPRSS} &= \frac{1}{m} \left( \sum_{i=1}^{h} X^{(2)}_{i(p(m+1)k)} + \sum_{j=h+1}^{m} X^{(2)}_{j(q(m+1)m)} + X^{(2)}_{((h+1)m)} \right), \quad \text{where} \quad h = (m-1)/2
\end{align*}
\]

The variance of \( \bar{X}^{(2)}_{DPRSS} \) and \( \bar{X}^{(2)}_{DPRSS} \) respectively are given by,

\[
\begin{align*}
Var(\bar{X}^{(2)}_{DPRSS}) &= \frac{1}{m^2} \left( \sum_{i=1}^{l} var(\bar{X}^{(2)}_{i(p(m+1)k)}) + \sum_{j=l+1}^{m} var(\bar{X}^{(2)}_{j(q(m+1)m)}) \right) \\
&= \frac{1}{m^2} \left( \frac{m}{2} \cdot var_{i(p(m+1)k)}^{(2)} + \frac{m}{2} \cdot var_{j(q(m+1)m)}^{(2)} \right) \\
&= \frac{1}{2m} \left( \frac{m}{2} \cdot var_{i(p(m+1)k)}^{(2)} + \frac{m}{2} \cdot var_{j(q(m+1)m)}^{(2)} \right) \\
Var(\bar{X}^{(2)}_{DPRSS}) &= \frac{1}{m^2} \left( \sum_{i=1}^{h} var(\bar{X}^{(2)}_{i(p(m+1)k)}) + \sum_{j=h+1}^{m} var(\bar{X}^{(2)}_{j(q(m+1)m)}) + var_{(h+1)m}^{(2)} \right) \\
&= \frac{1}{m^2} \left( \frac{m-1}{2} \cdot var_{i(p(m+1)k)}^{(2)} + \frac{m-1}{2} \cdot var_{j(q(m+1)m)}^{(2)} + \frac{1}{m^2} \cdot var_{(h+1)m}^{(2)} \right) \\
&= \frac{m-1}{2m^2} \left( \frac{m}{2} \cdot var_{i(p(m+1)k)}^{(2)} + \frac{m}{2} \cdot var_{j(q(m+1)m)}^{(2)} + \frac{1}{m^2} \cdot var_{(h+1)m}^{(2)} \right)
\end{align*}
\]

The properties of DPRSS estimators are
If the parent distribution is symmetric about mean \( \mu \), then

The DPRSS estimator is unbiased about population mean.

\( Var(\bar{X}^{(2)}_{DPRSS}) < Var(\bar{X}^{(2)}_{RSS}) < Var(\bar{X}^{(2)}_{SRS}) \)

If the underlying distribution is asymmetric about mean \( \mu \), then it is found that

\( MSE(\bar{X}^{(2)}_{DPRSS}) < var(\bar{X}^{(2)}_{RSS}) < var(\bar{X}^{(2)}_{SRS}) \), where, MSE is the mean square error and

\( MSE(\bar{X}^{(2)}_{DPRSS}) = var(\bar{X}^{(2)}_{DPRSS}) + (bias(\bar{X}^{(2)}_{DPRSS}))^2 \)

IV. COMPARISON OF ESTIMATORS

We can compare the three estimators for \( \mu \) based on RSS, MRSS and DPRSS procedures. For this purpose, we define the following Relative Precisions (RP).

A. For rss

\[
RP_1 = \frac{Var(\hat{\mu})}{Var(\bar{\mu})}, \quad \text{if} \quad \hat{\mu} \quad \text{is an unbiased estimator}
\]
\[
\text{B. For mrss}
\]
\[
R_P_2 = \frac{\text{Var}(\hat{\mu})}{\text{Var}(\mu^{(1)})}, \text{ if } \mu^{(1)} \text{ is an unbiased estimator}
\]
\[
= \frac{\text{Var}(\hat{\mu})}{\text{MSE}(\mu^{(1)})}, \text{ if } \mu^{(1)} \text{ is a biased estimator}
\]

\[
\text{C. For dprss}
\]
\[
R_P_3 = \frac{\text{Var}(\hat{\mu})}{\text{Var}(\mu^{(2)})}, \text{ if } \mu^{(2)} \text{ is an unbiased estimator}
\]
\[
= \frac{\text{Var}(\hat{\mu})}{\text{MSE}(\mu^{(2)})}, \text{ if } \mu^{(2)} \text{ is a biased estimator}
\]
\[
\text{as } \text{MSE}(\mu^{(2)}) = \text{Var}(\mu^{(2)}) + (\text{bias})^2
\]

As we know from above results, there is no biased in population mean in case of symmetric distributions, we have to examine the PR for symmetric and asymmetric distribution. Table-1 shows the PR for 10 symmetric and asymmetric distributions for m=6, 7, 11, 12 for each simulation 50,000 iterations are performed for p=25%.

<table>
<thead>
<tr>
<th>Distribution</th>
<th>m</th>
<th>RSS Bias</th>
<th>MRSS Bias</th>
<th>DPRSS Bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniform(0,1)</td>
<td>6</td>
<td>3.400 0.000</td>
<td>3.114 0.000</td>
<td>14.966 0.000</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>3.815 0.000</td>
<td>3.706 0.000</td>
<td>21.332 0.000</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>6.213 0.000</td>
<td>5.617 0.000</td>
<td>45.425 0.000</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>6.500 0.000</td>
<td>6.649 0.000</td>
<td>64.737 0.000</td>
</tr>
<tr>
<td>Uniform(0,2)</td>
<td>6</td>
<td>3.400 0.000</td>
<td>3.132 0.000</td>
<td>15.167 0.000</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>3.815 0.000</td>
<td>3.671 0.000</td>
<td>22.021 0.000</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>6.6213 0.000</td>
<td>5.632 0.000</td>
<td>45.213 0.000</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>6.503 0.000</td>
<td>6.651 0.000</td>
<td>65.135 0.000</td>
</tr>
<tr>
<td>Normal(0,1)</td>
<td>6</td>
<td>3.191 0.000</td>
<td>3.593 0.000</td>
<td>10.609 0.000</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>3.585 0.000</td>
<td>3.927 0.000</td>
<td>17.809 0.000</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>5.112 0.000</td>
<td>5.980 0.000</td>
<td>31.127 0.000</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>5.237 0.000</td>
<td>6.127 0.000</td>
<td>36.426 0.000</td>
</tr>
<tr>
<td>Normal(1,2)</td>
<td>6</td>
<td>3.110 0.000</td>
<td>3.445 0.000</td>
<td>10.952 0.000</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>3.535 0.000</td>
<td>4.251 0.000</td>
<td>13.359 0.000</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>5.195 0.000</td>
<td>6.240 0.000</td>
<td>35.046 0.000</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>5.652 0.000</td>
<td>6.412 0.000</td>
<td>36.958 0.000</td>
</tr>
<tr>
<td>Logistic(-1,1)</td>
<td>6</td>
<td>2.668 0.000</td>
<td>3.592 0.000</td>
<td>11.207 0.000</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>3.243 0.000</td>
<td>4.112 0.000</td>
<td>12.428 0.000</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>4.599 0.000</td>
<td>6.755 0.000</td>
<td>34.804 0.000</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>4.911 0.000</td>
<td>6.728 0.000</td>
<td>34.315 0.000</td>
</tr>
<tr>
<td>Exponential(1)</td>
<td>6</td>
<td>2.135 0.000</td>
<td>2.995 0.219</td>
<td>9.294 0.007</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>2.564 0.000</td>
<td>3.213 0.049</td>
<td>8.219 0.015</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>3.671 0.000</td>
<td>3.542 0.105</td>
<td>28.555 0.001</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>3.922 0.000</td>
<td>4.693 0.061</td>
<td>8.303 0.083</td>
</tr>
</tbody>
</table>
From above, we get the following information

A gain in efficiency attained using DPRSS for estimation population mean for symmetric distribution. As example for N(1,2) with \( m = 12 \), the relative efficiency of the DPRSS is 36.958 comparing it, with RSS and MRSS 5.652 and 6.412.

For asymmetric distribution, gain in efficiency is attained with smaller bias using DPRSS. For example, for Weibull with \( m = 12 \), the relative efficiency of DPRSS is 8.480 with bias 0.249 for estimating population mean having parameter 1 and 3, comparing with RSS and MRSS is 3.960 and 4.751 with bias 0.185.

V. RELATIVE SAVING

From relative precision, we have

\[
RP_2 = \frac{\text{Var}(SRS)}{\text{Var}(DPRSS)} = \frac{\text{Var}(\hat{\mu})}{\text{Var}(\hat{\mu}^{(2)})} = \frac{\sigma^2}{m} - \frac{1}{m^2} \sum_{i=1}^{m} (\mu_i^{(2)} - \mu_i^{(1)})^2 - \frac{1}{m} \sum_{i=1}^{m} (\mu_i^{(1)} - \mu)^2
\]

\[
= \frac{1}{1 - \frac{1}{\sigma^2} \left[ \frac{1}{m} \sum_{i=1}^{m} (\mu_i^{(2)} - \mu_i^{(1)})^2 + \frac{1}{m} \sum_{i=1}^{m} (\mu_i^{(1)} - \mu)^2 \right]} = \frac{1}{1 - RS^*}
\]

Where, \( RS^* = \frac{1}{m \sigma^2} \left[ \sum_{i=1}^{m} (\mu_i^{(2)} - \mu_i^{(1)})^2 + \sum_{i=1}^{m} (\mu_i^{(1)} - \mu)^2 \right] \) is called relative saving (RS) for DPRSS.

\[
RS = \frac{\text{Var}(\hat{\mu}) - \text{Var}(\hat{\mu}^{(2)})}{\text{Var}(\hat{\mu})}
\]

Similarly, we can have RS for RSS

\[
RS = \frac{1}{m \sigma^2} \left[ \sum_{i=1}^{m} (\mu_i^{(1)} - \mu)^2 \right]
\]

Hence, comparing \( RS^* \) and RS, we have

Relative Saving for DPRSS > Relative Saving for RSS
VI. APPLICATION TO REAL DATA SET

For the performance of mean estimation using a collection of real data set, which consists of the olive yield of each of 64 trees (for more details see Al-Saleh and Al-Omari (2002)). In this study, balanced ranked set sampling is considered. All the sampling done without replacement using the statistical programming 'R'. we obtained the mean and variance of sample mean using SRS, RSS, DPRSS technique using sample size m=3,4,5. We compare the averages of 70,000 sample estimate.

Let, \( t_i \) be the olive yield of the \( i^{th} \) tree \( i=1,2,...,64 \). The mean \( \mu \), and the variance \( \sigma^2 \) of the population, respectively, are,

\[
\mu = \frac{1}{64} \sum_{i=1}^{64} t_i = 9.766 \text{ kg/tree}
\]

\[
\sigma^2 = \frac{1}{64} \sum_{i=1}^{64} (t_i - \mu)^2 = 26.114 \text{ kg}^2/\text{tree}
\]

The skewness of the population is 0.475, indicates positively skewed, i.e., asymmetrical distribution. Hence, we have to find out \( MSE(\bar{X}_{DPRSS}^{(2)}) \) and efficiency values of \( \bar{X}_{RSS}^{(2)} \) and \( \bar{X}_{DPRSS}^{(2)} \) relative to \( \bar{X}_{SRS}^{(2)} \) for \( m=3, 4, 5 \).

TABLE 2: The efficiency values of RSS and DPRSS relative to SRS with sample size \( m=3,4,5 \)

<table>
<thead>
<tr>
<th>Sample size</th>
<th>methods</th>
<th>mean</th>
<th>Variance</th>
<th>efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>m=3</td>
<td>SRS</td>
<td>9.787</td>
<td>8.344</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>RSS</td>
<td>9.784</td>
<td>4.294</td>
<td>1.954</td>
</tr>
<tr>
<td></td>
<td>DPRSS</td>
<td>10.185</td>
<td>MSE</td>
<td>4.741</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BIAS</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.760</td>
<td>0.407</td>
</tr>
<tr>
<td>m=4</td>
<td>SRS</td>
<td>9.784</td>
<td>6.159</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>RSS</td>
<td>9.775</td>
<td>2.564</td>
<td>2.383</td>
</tr>
<tr>
<td></td>
<td>DPRSS</td>
<td>10.899</td>
<td>MSE</td>
<td>2.960</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BIAS</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.070</td>
<td>1.271</td>
</tr>
<tr>
<td>m=5</td>
<td>SRS</td>
<td>9.777</td>
<td>4.843</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>RSS</td>
<td>9.775</td>
<td>1.696</td>
<td>2.870</td>
</tr>
<tr>
<td></td>
<td>DPRSS</td>
<td>9.852</td>
<td>MSE</td>
<td>8.061</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BIAS</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.598</td>
<td>0.111</td>
</tr>
</tbody>
</table>

On the basis of above table, the DPRSS mean at any stage is close to the population mean 9.766, and there is a bias along with MSE as it is a asymmetrical distribution. Hence, DPRSS is much more efficient than SRS, RSS.

VII. SAMPLING WITH ERROR IN RANKING

In RSS, sampling mean is unbiased estimator of population mean without any proper information that, whether it is perfect or imperfect. Hence, it has a smaller variance as compared with SRS having same sample size. So Muttalak(2003) showed that QRSS with error in ranking is unbiased estimator of population mean with assumption that population is symmetric about its mean. Hence applying the above with DPRSS method in ranking with error may be defined as follows,

Let \( Y_{i[p(m+1),m]}^{(2)} \) and \( Y_{i[q(m+1)],m}^{(2)} \) be the first and last judgement double partitioned value of \( i^{th} \) sample \( i=1,2,...,m \) having errors in ranking. Then using DPRSS technique, the estimator of population mean with error in ranking can be represented as

\[
\hat{\mu}_{DPRSS_e}^{(2)} = \frac{1}{m} \sum_{k=1}^{r} \left( \sum_{i=1}^{l} X_{i[p(m+1)+]}^{(2)} + \sum_{i=l+1}^{m} X_{i[q(m+1)+]}^{(2)} \right), \quad 1 = m/2
\]
\[ \hat{Y}_{DPRSS}^{(2)} = \frac{1}{m_r} \sum_{k=1}^{r} \left( \sum_{i=1}^{h} X_{(i(m+1))k}^{(2)} + \sum_{i=h+1}^{m} X_{(i(m+1))k}^{(2)} \right), \quad h = (m-1)/2 \]

The estimator of population mean \( \mu \) in ranking with error having following properties,
\[ \hat{Y}_{DPRSS}^{(2)} \] with ranking in error is unbiased estimator of population mean with assumption that population is symmetric about its mean.
\[ \text{Var}(\hat{Y}_{DPRSS}^{(2)}) < \text{Var}(SRS) \] for symmetric distribution
and for asymmetric distribution about its mean, \[ \text{MSE}(\hat{Y}_{DPRSS}^{(2)}) < \text{Var}(SRS) \] for ranking in error.
The above properties can be proved based on Takahasi and Wakimoto(1968), Dell and Clutter (1972), Muttalak (2003) and Al-saleh and Al-kadiri (2000).

VIII. CONCLUSION

In this article, it is observed that, the estimator of proposed Double Partitioned Ranked Set Sampling (DPRSS) is unbiased for population mean and is more efficient than SRS, RSS in case of Symmetrical distribution. From NPR analysis, it is found that there is greater efficiency with smaller bias in case of estimating of population mean using DPRSS method for asymmetrical distribution. Again, using relative saving method, DPRSS has Greater RS as Compared with RSS.

REFERENCES


APPENDIX

A. Corollary-1:

Let \( X_i \) be the values assumed by the r.v. \( X \), having probability density function \( f_{X_i}(x) \) and cdf \( F_{X_i}(x) \) with mean and variance \( \mu \) and \( \sigma^2 \) respectively. A sample of size \( m \) was selected and ranked. Let \( X^{(1)}_{s,m} \) be the \( s^{th} \) smallest rank of the sample, where \( s=1,2,...,m \).

Then mean of \( X^{(1)}_{s,m} \), will be \( F^{-1}[\alpha(s)] \) and variance will be \( \sigma^2_{s,m} \).

Proof:

Let \( X_i \) be a random variable having mean \( \mu \) and variance \( \sigma^2 \) respectively and random sample of size \( m \) was selected and ranked. Let \( X_{s:m} \) be the \( s^{th} \) smallest value of the sample where \( S = 1, ......., m \).

Then pdf and cdf of \( X_s : m \) are

\[ f_{X_s : m}(x) = \frac{1}{B(s,m-s+1)} F^{s-1}(x) (1-F(x))^{m-s} f(x) \]

\[ F_{X_s : m}(x) = F_B(F(x); s,m-s+1) \text{ respectively.} \]

Where \( F_B \) (\( F(x); s, m-s+1 \)) follows a beta distribution function with parameters \( (S, m-S+1) \)

Let \( \mu_{X_s : m}^{(1)} \) = mean of \( X^{(1)}_{s,m} \)

and \( \sigma^2_{X_s : m}^{(1)} \) = variance of \( X^{(1)}_{s,m} \) respectively.

such that, Using Taylor series as given in David & Nagarajah (2003),
The variance of $X_{s:m}$ is given by

$$E\left(X_{s:m}^{(1)}\right) = \mu_{s:m}^{(1)} = \int x f_{s:m}(x) \, dx = F_{s:m}^{-1}(P_s)$$

and

$$F_{s:m}(x) = FB\left(F(x); s, m-s+1\right) = P_s$$

$$\Rightarrow \mu_{s:m}^{(1)} = F_{s:m}^{-1}(P_s) = F^{-1}[\alpha(s)]$$

where

$$\alpha(s) = PB\left(P_s; s, (m-s+1)\right)$$

is an partitioned function for beta distribution with $p_s=s/m+1$

Similarly,

$$F_{m-s+1:m}(x) = FB\left(F(x); m-s+1, s\right) = q_s$$

$$\Rightarrow \mu_{m-s+1:m}^{(1)} = F_{m-s+1:m}^{-1}(q_s) = F^{-1}\left[PB(q_s; m-s+1, s)\right]$$

$$= F^{-1}\left[1 - \alpha(s)\right]$$

where

$$PB(q_s; m-s+1, s) = PB\left(1-P_s; m-s+1, s\right) = 1 - PB\left(P_s; s, m-s+1\right) = 1 - \alpha(s)$$

and $p_s + q_s = 1$

If $f(x)$ follows symmetrical distribution for any $0 \leq \alpha(s) \leq 1$

Then

$$\Rightarrow q_s - \mu = \mu - P_s$$

$$\Rightarrow F^{-1}\left[1 - \alpha(s)\right] - \mu = \mu - F^{-1}[\alpha(s)]$$

$$\Rightarrow F^{-1}\left[1 - \alpha(s)\right] + F^{-1}[\alpha(s)] = 2\mu$$

$$\Rightarrow \mu_{s:m}^{(1)} + \mu_{m-s+1:m}^{(1)} = 2\mu$$

The variance of $X_{s:m}$ is given by

$$\sigma_{s:m}^{(1)} = \int \left(x - \mu_{s:m}^{(1)}\right)^2 f_{s:m}(x) \, dx$$

$$= \int (x - \mu)^2 f_{s:m}(x) \, dx - \left(\mu_{s:m} - \mu\right)^2$$

$$\Rightarrow \sigma_{s:m}^{(1)} + \left(\mu_{s:m} - \mu\right)^2 = \int (x - \mu)^2 f_{s:m}(x) \, dx$$

$$= \int (x - \mu)^2 \frac{1}{B(s; m-s+1)} F^{-1}(x) \left(1-F(x)\right)^{m-s} f(x) \, dx$$

$$= \int (x - \mu)^2 \tilde{f}(x) \, dx = \sigma^2$$

$$\Rightarrow \sigma_{s:m}^{(1)} + \left(\mu_{s:m} - \mu\right)^2 < \sigma^2$$

as

$$\frac{F^{-1}(x)\left[1-f(x)\right]^{m-s}}{B\left(s, m-s+1\right)} < 1$$

The variance of $X_{m:m}$ may also represented by

$$= \sigma_{s:m}^{(1)} = \int \frac{\left(F^{-1}(u) - F^{-1}[\alpha(s)]\right)^2}{B\left(s, m-s+1\right)} u^{s-1}(1-u)^{m-s} \, du$$

For symmetrical $f(x)$,
\[ \sigma^{(1/2)}_{s,m} = \frac{1}{B(m, m-s+1)} \int_{0}^{1} \left( F^{-1}(u) - F^{-1}[\alpha(s)] \right)^2 u^{s-1} (1-u)^{m-s} \, du \]
\[ = \frac{1}{B(m, m-s+1)} \int_{0}^{1} \left( F^{-1}(1-u) - F^{-1}[1 - \alpha(s)] \right)^2 u^{m-s} (1-u)^{s-1} \, du \]
\[ = \sigma^{(1/2)}_{s,m} \]

**B. Corollary - 2**

Let \( X^{(2)}_{s,m} \) be the \( s \)'th smallest value of a random sample of size \( m \). The sample was selected from a population having probability density function \( f_{s,m}(x) \) and cdf \( F_{s,m}(x) \) with mean and variance \( \mu_{s,m}^{(1)} \) and \( \sigma_{s,m}^{(1/2)} \) respectively. After ranking a size of \( m \) sample was selected and let \( x^{(2)}_{s,m} \) be the \( s \)'th smallest rank of the sample, where \( s=1,2,...,m \). Then mean of \( X^{(2)}_{s,m} \) will be \( F^{-1}[\alpha.s] \) and variance will be \( \sigma_{s,m}^{(2/2)} \).

**Proof:**

Let \( X^{(2)}_{s,m} \) be a random variable from population having mean \( \mu \) and variance \( \sigma^2 \) respectively. When a random sample from population of size \( m \) was selected and ranked.

Let, \( X^{(2)}_{s,m} = S^{(s)} \), smallest value of a random sample of size \( m \). The sample was selected from a population having probability density function \( f_{s,m}(x) \) with mean and variance \( \mu_{s,m}^{(1)} \) and \( \sigma_{s,m}^{(1/2)} \) respectively. After ranking a size of \( m \) sample was selected and let \( x^{(2)}_{s,m} \) be the \( s \)'th smallest rank of the sample, where \( s=1,2,...,m \). Then mean of \( X^{(2)}_{s,m} \) will be \( F^{-1}[\alpha.s] \) and variance will be \( \sigma_{s,m}^{(2/2)} \).

Let \( X^{(2)}_{s,m} \) be a random variable from population having mean \( \mu \) and variance \( \sigma^2 \) respectively. When a random sample from population of size \( m \) was selected and ranked.

Let, \( X^{(2)}_{s,m} = S^{(s)} \), smallest value of a random sample where \( S = 1, ..., m \).

Then pdf of population is

\[ f_{s,m}^{(1)}(x) = \frac{1}{B(s, m-s+1)} F_{s,m}^{(s-1)}(x) \left( 1 - F_{s,m}(x) \right)^{m-s} f_{s,m}(x) \]

where, the mean and variance of \( X^{(2)}_{ij} \) are \( \mu_{s,m}^{(1)} \) and \( \sigma_{s,m}^{(1/2)} \) respectively.

and also let \( x^{(2)}_{m-s+1:m} \) be the \((m-s+1)\)'th smallest value

\[ E(x^{(2)}_{s,m}) = \mu_{s,m}^{(2)} \]
\[ V(x^{(2)}_{s,m}) = \sigma_{s,m}^{(2)} \]

Then,

\[ \mu_{s,m}^{(2)} = \frac{1}{B(s, m-s+1)} \int_{0}^{1} F_{s,m}^{(-1)}(u) \left( 1 - F_{s,m}(u) \right)^{m-s} f_{s,m}(u) \, du \]

\[ = F_{s,m}^{(-1)}[\alpha(s)] \]

Again,

\[ \mu_{m-s+1:m}^{(2)} = \frac{1}{B(m-s+1, m)} \int_{0}^{1} F_{s,m}^{(-1)}[1 - \alpha(s)] \left( 1 - F_{s,m}(u) \right)^{m-s} f_{s,m}(u) \, du \]

\[ = q_{s,m}^{*} \]

For symmetric distribution for \( 0 \leq \alpha \leq 1 \)

\[ \Rightarrow q_{s,m}^{*} = \mu - P_{s,m} \]
\[ \Rightarrow F^{-1}[1 - \alpha.s] - \mu = \mu - F^{-1}[\alpha.s] \]
\[ \Rightarrow F^{-1}[1 - \alpha.s] + F^{-1}[\alpha.s] = 2 \mu \]
\[ \Rightarrow \mu_{m-s+1:m}^{(2)} + \mu_{s,m}^{(2)} = 2 \mu \]
The variance of $X_{s,m}^{(2)}$ will be

$$
\sigma_{s,m}^{(2)} = \int (x - \mu_{s,m}^{(2)})^2 f_{s,m}(x) \, dx
$$

$$
= \int (x - \mu_{s,m}^{(1)})^2 f_{s,m}(x) \, dx - (\mu_{s,m}^{(2)} - \mu_{s,m}^{(1)})^2
$$

$$
\Rightarrow \sigma_{s,m}^{(2)} + (\mu_{s,m}^{(2)} - \mu_{s,m}^{(1)})^2 = \sigma_{s,m}^{(1)}
$$

$$
as \int (x - \mu_{s,m}^{(1)})^2 f_{s,m}(x) \, dx = \sigma_{s,m}^{(2)}
$$

$$
\Rightarrow \sigma_{s,m}^{(2)} < \sigma_{s,m}^{(1)}
$$

Again

$$
\Rightarrow \sigma_{s,m}^{(2)} + (\mu_{s,m}^{(2)} - \mu_{s,m}^{(1)})^2 + (\mu_{s,m}^{(1)} - \mu)^2 = \sigma_{s,m}^{(1)} + (\mu_{s,m}^{(1)} - \mu)^2 = \sigma_{s,m}^{(2)}
$$

$$
\Rightarrow \text{var}(DPRSS) < \text{var}(RSS) < \text{var}(SRS)
$$

The variance of $X_{s,m}^{(2)}$ may also be represented as

$$
= \sigma_{s,m}^{(2)} = \int \left( F_{s,m}^{(1)}(u) - F_{s,m}^{(1)}[\alpha] \right)^2 \frac{u^{s-1}(1-u)^{m-s}}{B(s, m-s+1)} \, du
$$

For symmetrical $f(x)$,

$$
= \int \left( F_{s,m}^{(1)}(1-u) - F_{s,m}^{(1)}[\alpha] \right)^2 \frac{u^{s-1}(1-u)^{m-s}}{B(m-s+1, s)} \, du
$$

$$
= \int \left( F_{s,m}^{(1)}(1-u) - F_{s,m}^{(1)}[1-\alpha] \right)^2 \frac{u^{s-1}(1-u)^{m-s}}{B(m-s+1, s)} \, du
$$

$$
= \sigma_{m-s+1,m}^{(2)}
$$

C. Corollary-3

1. $\mu_{DPRSS}$ is an unbiased estimator of the population mean, for given assumption that population is symmetric about its mean.

Proof:

For $k^{th}$ cycle and $i^{th}$ sample,

D. If $m$ is even,

$$
\left[ x_{(2)}^{(2)}(p(m+1))k \right. \cdot x_{(2)}^{(2)}(p(m+1))k \cdot \ldots \cdot x_{(2)}^{(2)}(p(m+1))k \left\right] = \left[ x_{(2)}^{(2)}(m+1)k \right. \cdot x_{(2)}^{(2)}(m+1)k \cdot \ldots \cdot x_{(2)}^{(2)}(m+1)k \right]
$$

$x_{(2)}^{(2)}(q(m+1))k$ is the sample of size DPRSSE.
\[ \Rightarrow \mu^{(2)}_{\text{DPRSSE}} = \frac{1}{m} \left( \sum_{i=1}^{\ell} x_{i(s,m)}^{(2)} + \sum_{j=\ell+1}^{m} x_{j(m-s+1;m)}^{(2)} \right) \]

\[ \Rightarrow E \left( \mu^{(2)}_{\text{DPRSSE}} \right) = \frac{1}{m} \left( \sum_{i=1}^{\ell} E(x_{i(s,m)}^{(2)}) + \sum_{j=\ell+1}^{m} E(x_{j(m-s+1;m)}^{(2)}) \right) \]

\[ = \frac{1}{m} \left( m \cdot \mu^{(2)}_{s;m} + \frac{m}{2} \mu^{(2)}_{m-s+1;m} \right) \]

\[ = \frac{1}{m} \times \frac{m}{2} \left( \mu^{(2)}_{s;m} + \mu^{(2)}_{m-s+1;m} \right) \]

\[ = \frac{1}{2} \times 2 \mu = \mu \]

\[ E. \text{ If } m \text{ is odd}, \{ x_{\frac{m-1}{2}, (m+1)k}^{(2)}, x_{\frac{m-1}{2}, 2(m+1)k}^{(2)}, \ldots, x_{\frac{m-1}{2}, (m+1)k}^{(2)} \} \text{ is the sample of size DPRSSO.} \]

\[ \Rightarrow \mu^{(2)}_{\text{DPRSSE}} = \frac{1}{m} \left( \sum_{i=1}^{h} x_{i(s,m)}^{(2)} + \sum_{j=h+2}^{m} x_{j(m-s+1;m)}^{(2)} + x_{\frac{m-1}{2}, \frac{m+1}{2}}^{(2)} \right) \]

\[ \Rightarrow E \left( \mu^{(2)}_{\text{DPRSSE}} \right) = \frac{1}{m} \left( \sum_{i=1}^{h} E(x_{i(s,m)}^{(2)}) + \sum_{j=h+2}^{m} E(x_{j(m-s+1;m)}^{(2)}) + E\left(x_{\frac{m-1}{2}, \frac{m+1}{2}}^{(2)}\right) \right) \]

\[ = \frac{1}{m} \left[ \frac{m-1}{2} \left( \mu^{(2)}_{s;m} + \mu^{(2)}_{m-s+1;m} \right) + \mu \right] = \mu \]

Hence, \( \hat{\mu}^{(2)}_{\text{DPRSSE}} \) is an unbiased estimator of the population mean.

\[ F. \text{ Corollary-4} \]

Var(\( \overline{X}_{\text{DPRSSE}} \)) is less than each of Var(\( \overline{X}_{\text{SRS}} \)) and Var(\( \overline{X}_{\text{RSS}} \)).

Proof:

For m is even,

Then Variance will be

\[ \Rightarrow \text{var}(\hat{\mu}_{\text{DPRSSE}}) = \frac{1}{m^2} \left( \sum_{i=1}^{m/2} \text{var}(X_{i(s;m)}^{(2)}) + \sum_{j=m/2+1}^{m} \text{var}(X_{j(m-s+1;m)}^{(2)}) \right) \]

\[ = \frac{1}{2m} \left( \sigma_{s;m}^{(2)} + \sigma_{m-s+1;m}^{(2)} \right) = \frac{\sigma_{s,m}^{(2)}}{m} \]

\[ \Rightarrow \text{var(DPRSSE)} < \text{var(RSS)} < \text{var(SRS)} \]

For m is odd,
Then Variance can be defined as

\[
\Rightarrow \text{var}(\hat{\mu}_{\text{DPRSSO}}) = \frac{1}{m} \left( \sum_{i=1}^{m-1/2} \text{var}(X_{i(s;m)}^{(2)}) + \text{var}(X_{m+1/2;m}^{(2)}) + \sum_{m+1/2}^{m} \text{var}(X_{m-s+1;m}^{(2)}) \right)
\]

\[
= \frac{1}{m^2} \left( \frac{m-1}{2} \left( \frac{\sigma_{s,m}^{(2)}}{2} + \sigma_{m-s+1;m}^{(2)} \right) + \frac{m}{2} \left( \frac{\sigma_{s,m}^{(2)}}{2} + \sigma_{s,m}^{(2)} \right) \right)
\]

\[
= \frac{1}{m} \sigma_{s,m}^{(2)}
\]

\[
\Rightarrow \text{var}(\text{DPRSSO}) < \text{var}(\text{RSS}) < \text{var}(\text{SRS})
\]