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Summary:

The Sampling Method of the 1998 Norwegian Travel Survey

An analysis of estimator properties using WesVar

Usual estimators are biased when using Gallup sampling

Bias and sampling errors with an undocumented two stage cluster sampling scheme utilised by an interview organisation for a number of social and environmental surveys in Norway has been analysed analytically and by numerical means. In particular, the sampling method was used for the 1998 Norwegian Travel Survey with 6061 respondents.

Primary sampling units in this sampling scheme are households drawn from a national telephone directory. The person "over 13 years of age and who last celebrated their birthday" is thereafter selected. As the sampling fraction at the second stage of the sampling is inversely proportional to the number of household members over 13 years of age, the sampling method results in an overrepresentation of people from one-person households at the expense of people from three- and four +-person households.

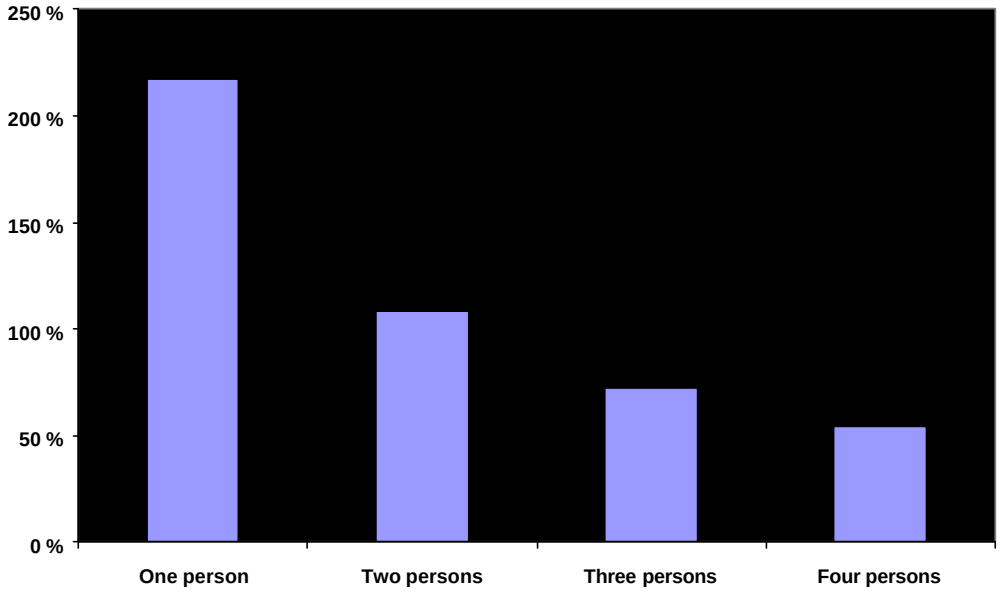

Figure S.1: Number of respondents from households of different sizes using the Gallup sampling method relative to that of a simple random sample of persons. The 1998 Norwegian Travel Survey. N=6061.

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Travel behaviour is substantially dependent on household economy and the number of cars in the household. Both of these variables are strongly correlated with household size. With data from both the 1985 and the 1998 Norwegian travel surveys it is thus shown in this working report that sample means provided by statistical packages such as SPSS are biased estimators for travel behaviour indicators in the population when the observations have been sampled according to the Gallup sampling scheme.

In most cases the sample means, here called "Gallup estimators" will underestimate the number of trips, trip length and trip duration. There are exceptions. While larger households shop more, the number of shopping trips is also shared by more people, resulting in fewer trips per person.

Ratio to size estimators analysed analytically and numerically

Fortunately, the bias inherent in the Gallup estimators was discovered during the planning of the 1998 Norwegian Travel Survey. It was therefore decided to use the sampling method, but replace the Gallup estimators with ratio to size estimators that are near unbiased. The ratio to size estimators – see figure S.2 – can be implemented by simply weighing the SPSS data file with a weighing factor proportional to the number of persons in the household over 13 years. This weighing of the data file means that the sample means provided by SPSS in reality are ratio to size estimators. At the same time such a weighing scheme inflates sample sizes, resulting in SPSS showing standard errors that are too small.

The standard error estimates for the sample means calculated from data sampled by the Gallup method differ significantly from the estimated standard errors of the ratio to size estimators. In order to estimate the size of the standard errors, a recent addition to SPSS, WesVar Complex Samples version 3.0 was acquired. This software package uses replication methods to provide the relevant standard errors numerically.

The idea behind replication methods is to calculate the estimate of interest from the full sample as well as each sub-sample or replicate. The variation between the replicate estimates and the full sample estimate is then used to estimate the variance for the full sample.

In practice, the sample size is expanded 100 times by sampling with replacement and variance estimates obtained from the equation:

$v(\hat{q}) = \frac{G-1}{G}\sum_{g=1}^{G}(\hat{q}_{(g)} - \hat{q})^2$ where $\hat{q}_{(g)}$ signifies the value of the estimator calculated for the g' th subsample, and G = 100.

Given the scant experience with the package it was decided to validate the numerically derived results with those provided by analytic means.

Gallup sampling method throws out 15% of the respondents

An equation describing the relative efficiency of the ratio to size estimator with the Gallup sampling method was developed from an elaboration of a formula provided

by Cochran (1977). Simplified analyses show that the ratio estimators on the average have a mean square error 118% that of a simple random sample of the same size. Or equivalently – having a mean square error equal to that of a simple random sample with 15% of the interviews thrown out. This calculation was cross-validated using WesVar later in the project, and the results do indeed coincide.

A more precise calculation of the Mean Square Errors (MSE) associated with the ratio to size estimators of travel behaviour indicator, see figure S.2, has also been cross validated and found to be correct.

$$\text{Ratioestimator}: \hat{\bar{\bar{Y}}}_R = \frac{\sum_{i=1}^{n} M_i \bar{y}_i}{\sum_{i=1}^{n} M_i} = \frac{\sum_{i=1}^{n} M_i y_i}{\sum_{i=1}^{n} M_i} : n(\hat{\bar{\bar{Y}}}_R) \approx \frac{\sum_{k=1}^{K} k^2 n_k (\hat{s}_k^{\,2} + (\bar{y}_k - \hat{\bar{\bar{Y}}}_R)^2)}{M_s^{\,2}})$$

Figure S.2: Ratio to size estimator and its associated mean square error. n_k=Number of households size k, k=1..K. M_i= number of household members >13. M_s= M_i summed over all=n households. $\hat{s}_k$ =estimated variance of y, y_k=sample mean for household group k.

Successful inclusion of regional samples improves precision

The successful harmonising of the 1998 Norwegian Travel Survey with concurrent regional travel surveys resulted in the incorporation of 2777 additional regional interviews from three counties. The interviews were incorporated in the data file by means of a poststratification stage. The included interviews are shown both analytically and numerically to improve the precision of the estimators somewhat more than was lost by the use of the Gallup sampling method. The overall gain is thus small and can be implemented by scaling the resulting data file to show 6175 respondents instead of the 6061 actually in the national sample. Again, both the analytic and numerically derived results coincide.

WesVar has proved its usefulness

This working report documents that it is possible to derive the standard errors of the ratio to size estimators analytically. It is also straightforward to provide approximate results for the gain in precision resulting from the inclusion of the regional samples. Detailed results when both household weights and post-stratification are in effect simultaneously, are, however, not as easily derived. It is also not feasible to do calculations based on the analytic results for the cells of each and every cross-tabulation.

For such purposes the use of replication methods provided by WesVar is a real bonus. While WesVar is a recent addition to SPSS, replication methods have been around for at least 20 years. In particular, their use in the Norwegian Travel Surveys with an initial sample size of 6000 + should be problem free[1]. It is therefore the authors' considerate opinion that WesVar should be used for such

[1] The high level non-response is of course a problem that has to be dealt with separately.

estimates in the future. While not extensively tested, the tests and comparisons documented in this working report are sufficiently consistent to allow such a recommendation. WesVar has passed with flying colours with one possible question mark concerning the number of replications necessary to obtain precise estimates in special cases. The rules of thumbs provided for using SPSS with the weighed data file gives the means of cross-validating the results and detecting any gross errors. (WesVar also provides several other replication methods than the one utilised here. These have not been tested.)

Other sources of error

The reason for the large survey sample in the Norwegian Travel Surveys (6000 +) is to provide precise estimators for cells in cross-tabulations and for comparisons between survey results for different years. With a non-response of 50% it is questionable whether the large sample size is really cost-effective and whether the differences in precision discussed in this paper are large in comparison with the errors caused by non-response.

It is thus mandatory to reduce the level of non-response. Also it is necessary to ascertain the properties of non-respondents as part of the quality assurance of the travel survey. For such work it is strongly recommended to use a sampling frame from public records targeting specific people and not use telephone directories as a sampling frame.

The Gallup method was also utilised in the 1992 Norwegian Travel Survey. As the telephone numbers used initially were provided in a non-standard manner, the results documented above are not directly applicable.