Exploring Sampling Techniques to Reduce Respondent Burden

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Outline

- Purpose of research
- Brief review of sampling techniques
  - Probability sampling
  - Model-based sampling
  - Model-aided sampling
  - Model-assisted sampling
- Sampling procedures used at NASS
- Coordination function
- Simulation study
- Summary

Purpose of Research

Adopting a sampling design that will allow for

- Efficient estimators
  - Consistent
  - Efficient with respect to the variance
  - Unbiased
- Fixed sample size
- Simple implementation
- Optimal coordination of surveys
  - Small respondent burden

Review of Sampling Techniques

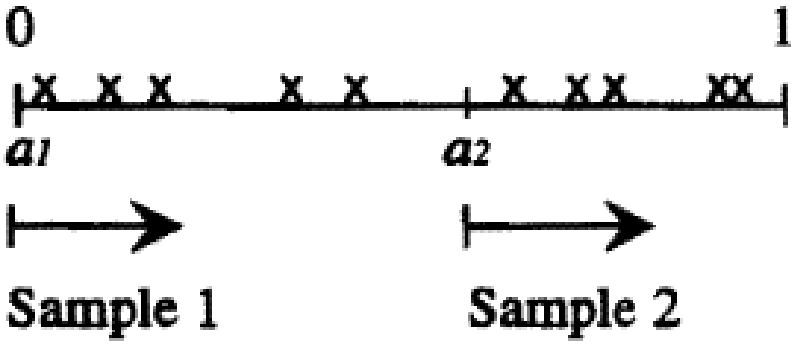
- Permanent random numbers, PRNs
- Poisson (or Bernoulli) Sampling
- Collocated random numbers, CRNs
- Births and deaths, and PRNs/CRNs
- Sample rotation
- Probability proportional to size
- Model-based, Model-aided, Model-assisted survey sampling
- Coordination function

Permanent random numbers (PRNs)

- Each unit $U_1, \ldots, U_N$ is associated with a random number X_i, $X_i \sim U(0,1)$, and X_i are i.i.d
- All the units are ordered ascendingly based on the random number $X_i s$ (i.e. order the $X_i s$ in ascending order)
- The first *n* units on the list are selected
- Applied in Jales technique (Ohlsson, 1992)
  - Associate the same random number (PRN) with the same unit
  - New businesses (births) are assigned new random numbers and closed-down (deaths) are withdrawn from the register

Positive/Negative Coordination of Two Surveys

- PRN (i.e. Permanent Random Number) is the same random number associated with the same unit



- Negative coordination starting points in each survey are far away from one another; a_1 and a_2 are far away

- Positive co-ordination is vice versa; a_1 and a_2 close to one another (Ohlsson,1992)

PRN- Equal Probability Starting Unit (EPSU)

- Sampling within an interval $(a\ b) \subset (0,1)$ instead of beyond some point a_0 is known as a Poisson sampling (Ohlsson, 1992) or Bernoulli sampling (Sarndal, Swensson, & Wretman, 1992)
- Yields fixed sampling fraction but not a fixed sample size
- Disadvantages
  - If the goal is to coordinate two or more surveys by minimizing the overlap between them, if not well distributed, PRNs may cause problems
  - If all random numbers are falling in a small range, there would be starting points that will not yield points for selection
  - Unbiased Horvitz –Thompson estimator is known to have very poor precision in connection with Poisson sampling (Ernst & Casady, 2000, and Ohlsson,1992)

Application of Permanent Random Number

- System for coordination of samples from the business register at Statistics Sweden (SAMU)
- All surveys in SAMU are stratified according to industry
  - Three hierarchical levels of stratification by industry from which to choose
  - Several other qualitative variables for stratification and selection, including but not limited to regions and variables related to ownership
  - Poisson sampling is used for sample selection
- SAMU has a built-in allocation system that can perform Neyman allocation on any of the size variables

Collocated Random Numbers

- Generate PRN $R_i \sim U(0,1)$ for each $X_i s$
- Record the rank R_i for each X_i
- Generate a single random number $\varepsilon \in U(0,1)$ and calculate

  $u_i = (R_i - \varepsilon)/N_0$ for each unit on the frame
- These u_i serve as new permanent random numbers for population units (Ernst & Casady, 2000)
- Spaces PRNs assigned to the population units equally
- Eliminates the clumping that can occur with PRNs
- For sample size of 20 or larger, PRN and CRN techniques have similar performance (Ernst & Casady, 2000)

Application of Collocated Random Numbers

- U.S. Bureau of Labor Statistics (BLS) routinely conducts several large-scale establishment surveys in a Federal/State cooperative environment
  - Current Employment Statistics (CES), Occupational Employment Statistics (OES), Occupational Safety and Health (OSH), Job Opening and Labor Turnover Statistics (JOLTS)
- Primary source of BLS is business establishment list (BEL)
  - Reports for each unemployment insurance (U.I.) account for 7 million records
- CRN used by BLS
  - to achieve the amount of sample overlap desired within a survey from one time period to another
  - to minimize the overlap in samples among different surveys

Births and Deaths from the Sample

- Birth: unit was not in the sample previously, but is rotated in at a later time
- Two ways of PRN deal with birth
  - Create separate strata for birth, apply the same strata definition, or broader strata definition
- CRN dealing with birth
  - A random number from $U(0,1)$ is drawn independently for each birth unit, the entire population is re-ordered
- Death: unit was in sample previously, but is rotated out at a later time
- Appropriate when entire sample is being rotated
- Used by several agencies, such as: Bureau of Labor Statistics (BLS) for Occupational Employment Statistics Survey (Ernst & Casady, 2000)

Probability Proportional to Size – πps Scheme

- Inclusion probabilities π_k proportional to size s_k, $k = 1,2, \ldots, N$
- Admits sample coordination over time and between surveys
- $y = y_1, y_2, \ldots, y_k, \ldots y_N$ – unknown characteristic of population
- $s = s_1, s_2, \ldots, s_k, \ldots s_N$, where $s_k > 0$, and *k = 1, 2, . . . , N* - known characteristics of population

$$\lambda_k = n s_k \Big/ \sum_{j=1}^{N} s_j$$

- Systematic πps, Random frame order, Frame ordered by size πps, Sunter πps

Traditional Probability Sampling

- For well-defined population of interest, design the sample so that selected units are in some sense representative of the whole population (Smith, 1983)
- Random selection process with known probabilities of selection (King, 1985)
- Can support inference only to the population implied by the sampling frame

Model-based Sampling Approach

- Model used to define the distribution of target population with respect to variable of interest (Stephenson, 1979)
- Not selected randomly and sampling weights not used
- Often incorporates poststratification for making descriptive inference of a specific population (Smith, 1983)
- Inference based on superpopulation model, using *a priori* sampling distribution achieved during data collection (King, 1985 and Deville, 1991)

Model-Aided Survey Sampling (MAS)

- Combining traditional probability sampling with quota sampling is a type of model-based sampling
- Units not selected randomly and sampling weights not used
- Simulation study of O*Net data (Berzofsky, 2008 and 2012) shows:
  - MAS retains probabilistic features underlying traditional sampling method
  - Keeps biasedness as traditional method, and if model assumptions hold, there is no bias in estimates produced (Deville,1991)
  - Reduces the response burden
  - Corrects skewness (avoids non-response bias) of survey
- MAS may not be effective design for initial data collection study for which little prior information exists about target population

Model assisted survey sampling

- Choosing an estimator that leads to a valid inference with respect to the sampling design, even if the model is misspecified by considering an optimal strategy rather than an optimal estimator

Model-based or model-assisted?

- When the superpopulation has fully explainable heteroscedasticity, one chooses the same sampling design for both approaches with inclusion probabilities proportional to standard deviations of errors of the model

- Horvitz-Thompson estimator is BLUE under model-assisted approach

Sampling Procedures Used at NASS

- Multivariate Probability Proportional to Size (MPPS)- employed in Crop Survey (CS)
- Sequential Interval Poisson Sampling (SIP)- employed in Agricultural Resource Management Survey (ARMS) to control overlap between ARMS from the previous year and the Crop APS sample for current year
- Stratified sampling - employed in all other surveys
- All fit into probability sampling approach

Multivariate Probability Proportional to Size (MPPS) at NASS

- Each farm i has unique probability π_i of selection,

  $$\pi_i = \min\{1, \max\{p_i^{(m)}, m = 1 \ldots M\}\},$$

  where $p_i^{(m)}$ is item m selection probability

- Probability is determined by available auxiliary data through optimal allocation consideration

- General assumption: variance is proportional to (a power of) the auxiliary data value, incorporating a desired item-level sample size

Sequential Interval Poisson Sampling (SIP) at NASS

- Employed in Agricultural Resource Management Survey (ARMS)
- Control overlap between ARMS from previous year and Crop APS sample for current year
- Sampling process where each element of population sampled is subjected to independent Bernoulli trial
- Each element of population may have different probability of being included in sample

Coordination Function and Response Burden

- Measurable and preserves *U(0,1)* probability
- Quantifies response burden, which enables to easily minimize or maximize it (Guggemos, 2012)
- Response burden is defined as: the number of times a unit is selected to participate in a survey

Steps:

- First sample S_1 is selected based on the permanent random number. Cumulative response burden is calculated for each chosen unit
- The *n*th sample S_n is selected using coordination function to update the random number for each unit and whether a unit will be selected based on its “new” random number

Coordination Function

- A simulation study is conducted, where 10 samples, consisting of 25 units each, are taken from the population of 100 simultaneously. The results showed:
  - Response burden is reduced by ~ 50%
  - It is quite robust against the volatility of parameters characterizing population and survey design
  - However, it is counterproductive when the sampling rate is too small

Simulation Results for Using Coordination Function in SRS

number of appearance	Coordination function(%)	SRS(%)	PPS(%)	SRS and PPS(%)
1	10.83	20.064	20.779	21.540
2	22.574	29.705	21.544	27.974
3	68.892	26.419	21.275	24.593
4	0.6671	15.615	17.081	15.458
5	0.0740	6.098	11.396	7.222
6	0.0039	1.713	5.375	2.483
7	0.0001	0.330	1.939	0.627
8	0	0.005	0.529	0.092
9	0	0.001	0.075	0.011
10	0	0	0.007	0

Coordination Function on Agricultural Yield Survey, Row Crop Survey, and Crop Sample Survey

number of appearance	Coordination function(%)	PPS(%)
1	79	76.3
2	21	22.8
3	0	0.9

Summary

- Sampling techniques along with their applications
- Coordination function tested on simulated data as well as on NASS survey data
- Coordination function works well if sampling rate is not too low

- Next step
  - Other sampling techniques will be tested in the future
  - Using simulated data and NASS survey data
  - Checking the efficiency of the estimator derived based on the new and current method.

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Any Questions?

Thank you!