Overview of Current Population Survey Methodology

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Abstract: The Current Population Survey (CPS) is one of the oldest, largest, and most well recognized surveys in the United States. It produces monthly household information about employment, unemployment, and other characteristics of the civilian non-institutionalized population. In this paper, we will evaluate the CPS sample design and estimation procedure, with specific attention to research problems in the areas of rotating panel design, sample size, systematic-sampling interval, AK composite estimate, and replication variance estimates. We will provide some comments and suggestions for future research, and suggest some ways to improve current CPS methods.

Key Words: Current Population Survey, Rotation Panel Design, AK Composite Estimate, Replication Variance Estimate

1. Background

The Current Population Survey (CPS), a household sample survey sponsored jointly by the U.S. Census Bureau and the U.S. Bureau of Labor Statistics (BLS), is the primary source of labor force statistics (LFS) for the population of the United States. The CPS is the source of numerous high-profile economic statistics, including the monthly national unemployment rate, and provides data on a wide range of issues relating to employment and earnings. The CPS also collects extensive demographic data that complement and enhance our understanding of labor market conditions in the nation overall, among many different population groups, in the states and in substate areas.

The CPS is a source of information not only for economic and social science research, but also for the study of survey methodology. The principal purpose of CPS is to report timely and accurately on the labor force data. The U.S. Census Bureau applies a probability sample to draw about 72,000 occupied households for the CPS. We conduct data collection during the calendar week that includes the 19th of the month. The questions refer to activities during the prior week, that is, the week that includes the 12th of the month. Housing units selected from all 50 states and the District of Columbia are in the survey for 4 consecutive months, out for 8 months, and then return for another 4 months before leaving the sample permanently. We call this a 4-8-4 rotation panel design. It ensures a high degree of continuity from one month to the next, one quarter to the next, as well as one year to the next. The 4-8-4 sampling scheme has the added

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benefit of allowing the constant replacement of the sample without excessive burden to respondents.

2. Survey Design

The sample design for CPS is a two-stage sample of approximately 72,000 assigned housing units to measure demographic and labor force characteristics of the civilian non-institutionalized population 16 years of age and older. Approximately 12,000 of the assigned housing units are selected under the State Children's Health Insurance Program (SCHIP) expansion that has been part of the official CPS sample since July 2001. The CPS draws housing units from lists of addresses obtained from the 2000 Decennial Census of Population and Housing. The sample is updated continuously for new housing built after Census 2000. The first stage of sampling involves dividing the United States into 2,025 primary sampling units (PSUs), which consist of a large county or a group of smaller counties. Every PSU falls within the boundary of a state. PSUs are also divided into two categories: self-representing (SR) PSUs and non-self-representing (NSR) PSUs. In general, a SR PSU is defined as a "large" PSU. Any PSU that is part of the 151 most populous metropolitan areas is a SR PSU. In addition, the two largest remaining PSUs for each state are SR PSUs. All PSUs in the states of Connecticut, Delaware, District of Columbia, Hawaii, New Hampshire, New Jersey, Rhode Island, and Vermont are SR PSUs. There are 446 SR PSUs containing roughly 70% of the total population. For NSR PSUs, we grouped them into strata based on homogeneity in terms of labor force and other social and economic characteristics that are highly correlated with unemployment, in such a way as to minimize between PSU variance. We select one PSU per stratum by probability proportional to size (PPS) restricted to the population 16+ as of Census 2000. This sampled PSU will represent the rest NSR PSUs in the Stratum. This is one of component of the variability in the CPS estimates. There are 824 PSUs selected for the CPS sample. Among them, 446 are SR PSUs and 378 are NSR PSUs.

In the second stage of sampling, a sample of housing units within the sampled PSUs is drawn. Clusters of 4 housing units are systematically drawn from sorted lists of blocks prepared as part of Census 2000. Housing units from blocks with similar demographic composition and geographic proximity are grouped together in the list. The CPS sample is usually described as a two-stage sample, but occasionally, a third stage of sampling is necessary when selected housing units are extremely large. Occasionally, the deviation is large enough to jeopardize the successful completion of a field representative's assignment. When these situations occur, a third stage of selection is conducted to maintain a manageable field representative's workload. The third stage is also called field subsampling.

Each month, interviewers collect data from the sampled housing units. A housing unit is interviewed for 4 consecutive months, dropped out of the sample for the next 8 months, and interviewed again in the following 4 months. Therefore, a sampled housing unit is interviewed eight times. Households are rotated in and out of the sample in a way that improves the accuracy of the month-to-month, quarter-to-quarter, and year-to-year change estimates. The rotation scheme ensures that in any single month, one-eighth of the housing units are interviewed for the first time, another eighth is interviewed for the second time, and so on. That is, after the first month, 6 of the 8 rotation panels will have been in the survey for the previous month: there is a 75 percent month-to-month overlap. After 3 months, 2 of the 8 rotation groups will be in the survey for the previous quarter, so that there is a 25 percent quarter-to-quarter overlap. When the system has been in full operation for 1 year, 4 of the 8 rotation groups in any month will have been in the survey for the same month, 1 year ago. There is a 50 percent year-to-year overlap. This rotation scheme upholds the scientific principles of probability sampling and each month's sample produces a true representation of the target population. The key advantage for the rotation design is that correlation between interviews reduces variance.

There also exist some disadvantages for the rotating panel design. For the CPS 4-8-4 rotation design, we have 8 independent panels. Each panel can produce an estimate of the total labor force statistics. In order to reach a certain precision of the estimation, it is necessary to maintain a minimum sample size for each panel, which requires a large total sample size. Secondly, for a fixed month, samples from each panel are drawn from the frames based on a different month. For example, frames from month-in-sample (MIS) 1 are lists of household addresses last month, and frames from MIS 8 are lists of household addresses 16 months ago. In many previous researches, rotation biases have been identified among the 8 panels. Finally, we remark that there can be some response burden for householders to answer a survey 8 times.

The CPS questionnaire is a completely computerized document that is administered by Census Bureau field representatives across the country through both personal and telephone interviews. Additional telephone interviewing is conducted from the Census Bureau's three centralized collection facilities in Hagerstown, Maryland, Jeffersonville, Indiana, and Tucson, Arizona. A personal-visit interview is required for all first month-in-sample (MIS) households because the CPS sample is strictly a sample of addresses. The U.S. Census Bureau does not know who the occupants of the sampled household are, or even whether the household is occupied or eligible for interview. Field Representatives (FRs) must also attempt to conduct a personal-visit interview for the fifth-month interview. After one attempt, a telephone interview may be conducted when the original householders still occupy the sample unit. This fifth month interview follows a sample unit's 8-month inactive period and is used to reestablish connection with the householders. Fifth-month householders are more likely than any other MIS householders to be a replacement household, that is, a replacement household in which all the previous month's residents have moved out and been replaced by an entirely different group of residents. This can and does occur in any MIS except for MIS 1 households. MIS 2, 3, 4, 6, 7, and 8 are eligible for telephone interviewing. We collect about 85 percent of these cases via the telephone.

Labor force statistics (LFS) is a popular international research topic. Many countries put efforts and resources into LFS. Table 1 provides comparisons on the rotation design, report period, monthly overlap, quarterly overlap, yearly overlap, and sample size among United States, Canada, Australia, United Kingdom, and Japan. The United Kingdom is the only country, which produces quarterly LFS reports, but no monthly report. Thus, their rotation design is very unique. They divide samples into 5 rotating panels. They interview in month 1, skip months 2 and 3, sample again in month 4, skip months 5 and 6, and so on until each panel has finished 5 interviews. Japan focuses on monthly and yearly LFS reports. Thus, their samples divide into 4 rotating panels with 50 percent monthly and yearly overlap. Their design has no quarterly overlap. Canada and Australia mainly publish monthly and quarterly LFS reports. Their design is unable to provide yearly LFS reports. The United States' 4-8-4 rotation design is a balanced design, which can readily produce monthly and yearly LFS reports as well as quarterly LFS reports if need.

Table 1: Summary of rotation design for several countries

	Rotation design	Report period	Monthly overlap	Quarterly overlap	Yearly overlap	Sample size
United States	4-8-4	Monthly	75%	25%	50%	72,000
Canada	6-0	Monthly	83%	50%	0%	53,000
Australia	8-0	Monthly	88%	63%	0%	29,000
United Kingdom	1-2-1-2-1-2-1-2-1-2	Quarterly	0%	80%	20%	20,000
Japan	2-10-2	Monthly	50%	0%	50%	40,000

Many household surveys are reported over time with the same or similar content and methodology to produce repeated measurements of key indicators that are used to assess how demographic, economic, and social conditions change. There are three common designs for repeated household surveys: independent, longitudinal, and repeated. For independent survey design, we independently select samples over time. These samples are normally different. They do not have correlations over time. For longitudinal survey design, survey units are followed indefinitely over time, and this has advantage that survey changes occur at the individual level. Repeated survey designs do not require the same units over time, but are designed for some overlap. The rotating panel design compromises between longitudinal and independent sample designs.

Sample sizes are determined by reliability requirements that are expressed in terms of the coefficient of variation (CV). The CV is a relative measure of the sampling error and is calculated as sampling standard error divided by the expected value of the given characteristic. The specified CV requirement for the monthly unemployment level for the U.S. is 1.9 percent when there is a 6 percent unemployment rate (UER). The 1.9 percent CV is based on the requirement that a difference of 0.2 percentage points in the unemployment rate for two consecutive months be statistically significant at a 90-percent confidence level. The required CV on the annual average unemployment level for each state, substate area, and the District of Columbia is 8 percent when the unemployment rate is 6 percent.

The CPS sample design calls for combining PSUs into strata within each state and for selecting one PSU from each stratum. For this type of sample design, sampling theory and cost considerations suggest forming strata with approximately equal population sizes. When the design is self-weighting (same sampling fraction in all strata) and one field representative is assigned to each sampled PSU, equal stratum sizes have the advantage of providing equal field representative's workloads. Thus, the objective of the stratification is to group PSUs with similar characteristics into strata having approximately equal populations. After stratifying the PSUs within the states, we calculate the overall sampling interval in each state. The overall state sampling interval is the inverse of the probability of selection of each housing unit in a state for a self-weighting design. By design, the overall state sampling interval is fixed, but the state sample size is not fixed, allowing growth of the CPS sample because of housing units built after Census 2000. All sampled units have equal weights. Self-weighting samples often yield smaller variance, and their sample statistics are more robust.

3. Estimation Method

3.1 Weighting

The Current Population Survey (CPS) is a multistage probability sample of housing units in the United States. It produces monthly labor force and related estimates for the total U.S. civilian non-institutional population and for various age, sex, race, and ethnic groups. In addition, estimates for a number of other population sub-domains of the nation are produced on a monthly, a quarterly, or a yearly basis. Each month a sample of eight panels is interviewed, with demographic data collected for all occupants of the sampled housing units. Labor force data are collected for persons 15 years and older. Each rotation group is a representative sample of the U.S. population. The labor force estimates are derived through a number of weighting steps in the estimation procedure.

In addition, the weighting at each step is replicated in order to derive variances for the labor force estimates. In this section, we discuss the CPS weighting procedure.

Distributions of demographic characteristics derived from the CPS sample in any given month will be somehow different from the true distributions even for such basic characteristics such as age, race, sex, and Hispanic ethnicity. These particular population characteristics are closely correlated with labor force status and other characteristics estimated from the sample. Therefore, the variance of sample estimates based on these characteristics can be reduced by the use of appropriate weighting adjustments when the sample population distribution is brought as closely into agreement as possible with the known distribution of the entire population with respect to these characteristics. This is accomplished by means of ratio adjustments. There are five ratio adjustments in the CPS estimation process: the first-stage ratio adjustment, the national coverage adjustment, the state coverage adjustment, the second-stage ratio adjustment, and the composite ratio adjustment.

The weighting procedures for producing national and state estimates from the CPS survey are defined in several steps:

- Design based weights derived from CPS sampling probabilities.
- Weight factor adjustment for nonresponse.
- First-stage ratio adjustment to reduce variances due to the sampling of PSUs.
- National and State Coverage adjustments to improve CPS coverage.
- Second-stage ratio adjustment to reduce variances by controlling CPS estimates of population to independent estimates of the current population.
- Composite estimate using estimates from previous months to reduce the variances.

In addition to estimates of basic labor force characteristics, several other types of estimates are also produced on a monthly, a quarterly, or a yearly basis. Each of these involves additional weighting steps to produce the final estimate. The types of characteristics include:

- Household-level estimates and estimates of married couples living in the same household using household and family weights.
- Estimates of earnings, union affiliation, and industry and occupation of second jobs collected from respondents in the quarter’s sample using outgoing rotation group weights.
- Estimates of labor force status by age for veterans and nonveterans using veterans’ weights.
- Estimates of monthly gross flows using longitudinal weights.
- Seasonally adjusted estimates for key labor force statistics.

3.2 Ratio Estimate

The main interest of CPS is the estimation of monthly totals of a given set of characteristics and their monthly changes. Let Y_t denote the unknown total for y at month t and let $\hat{Y}_{t,i}$ be the estimate of Y_t based on data in the ith rotation panel at month t, $i = 1, \ldots, 8$. As we described above, there are 7 steps of weighting adjustment to obtain $\hat{Y}_{t,i}$. These steps came from 3 categories: nonresponse adjustment, coverage adjustment (state, national), and calibration adjustment (state, race, ethnicity, age, and sex).

In the first-stage ratio adjustment, weights are adjusted so that the respective distributions of Black alone and non-Black alone census population from the sampled PSUs in a state corresponds to the Black alone and non-Black alone population distribution from the census for all PSUs in the state. In the national coverage ratio adjustment, weights are adjusted. So that the distribution of age-sex-race-ethnicity groups match independent estimates of the national population. In the state coverage ratio adjustment, weights are adjusted so that the distributions of age-sex-race groups match independent estimates of the state population. In the second-stage ratio adjustment, weights are adjusted so that aggregated CPS sample estimates match independent estimates of population in various age/sex/race and age/sex/ethnicity cells at the national level. Adjustments are also made so that the estimated state populations from CPS match independent state population estimates by age and sex.

The raking ratio estimate is

$$\hat{Y}_{t,i} = \sum_{j \in S_{ti}} b_{ti,j}\, y_{ti,j}$$

where $b_{ti,j}$ are the calibrated weights, defined to minimize the distance measure

$$\sum_{j \in S_{ti}} b_{ti,j}\, ln\left(b_{ti,j}/w_{ti,j}\right)$$

subject to $\sum_{j \in S_{ti}} b_{ti,j}\, x_{ti,j} = X_{ti}$ (the calibration equation). Here, X_{ti} is an auxiliary variable called the population control variable.

After weighting and calibration, we have the final form of estimation for CPS, which is generally called the Ratio Estimate in the papers related to the CPS:

$$\hat{Y}_t^1 = \frac{1}{8} \sum_{i=1}^{8} \hat{Y}_{t,i}$$

Once each record has a second-stage weight, an estimate of level for any given set of binary characteristics identifiable in the CPS can be computed by summing the second stage weights for all the sample cases that have that set of characteristics. This type of estimate has been variously referred to as a Horvitz-Thompson estimate, a two-stage Ratio Estimate, or a simple weighted estimate. However, the estimate actually used for the derivation of most official CPS labor force estimates that are based upon information collected every month from the full sample is a composite estimate.

3.3 Difference estimate

As we mentioned above, our main purpose in CPS is to estimate not only the monthly total of a given set of characteristics, but also the monthly change. The difference estimate is the most common and more efficient method to measure the difference between months. First, we estimate the difference between the current and previous month $t-1$. From the sample design, there is 75 percent monthly overlap. We have the same households in 6 out of the full set of 8 panels. Using these overlap units, we are able to estimate the difference $\hat{\Delta}_t$, where $\hat{\Delta}_t = \frac{1}{6}\sum_{i \in s}\left(\hat{Y}_{t,i} - \hat{Y}_{t-1,i-1}\right)$, $s = \{2,3,4,6,7,8\}$, and $\hat{Y}_{t-1}$ is the estimate of Y_{t-1}. Then, the difference estimate $\hat{Y}_t^2$ is equal to $\hat{\Delta}_t$ plus $\hat{Y}_{t-1}$, that is,

$$\hat{Y}_t^2 = \hat{Y}_{t-1} + \hat{\Delta}_t.$$

The CPS 4-8-4 rotating panel design compromises between longitudinal and independent sample designs. The Ratio Estimate $\hat{Y}_t^1$ is a popular method to estimate the total, and the difference estimate $\hat{Y}_t^2$ is usually applied when we deal with a longitudinal survey design. Since the Ratio Estimate does not use the previous monthly information and the difference estimate does not use all the data, it is natural to introduce a composite estimate, which compromises Ratio Estimate and difference estimates, that is,

$$\hat{Y}_t^c = (1-K)\hat{Y}_t^1 + K\hat{Y}_t^2$$

where K is between 0 and 1 and is determined empirically.

In general, a composite estimate $\hat{Y}_t^c$ is a weighted average of Ratio Estimate $\hat{Y}_t^1$ and difference estimate $\hat{Y}_t^2$. The composite estimate from the CPS has historically combined two estimates. The first of these is the Ratio Estimate described above. The second consists of the composite estimate for the preceding month and an estimate of the change from the preceding to the current month. The estimate of the change is based upon data from that part of the sample, which is common to the two months (about 75 percent). The higher month-to-month correlation between estimates from the same sample units tends to reduce the variance of the estimate of month-to-month change. Although the average improvements in variance from the use of the composite estimate are greatest for estimates of month-to-month change, improvements are also realized for estimates of change over other intervals of time and for estimates of levels in a given month (Breau and Ernst, 1983). Prior to 1985, the two estimates described in the preceding paragraph were the only terms in the CPS composite estimate and were given equal weight.

3.4 AK composite estimate

Since 1985, the weights for the two estimates have been unequal and a third term has been included, an estimate of the net difference between the incoming and continuing parts of the current month's sample. Effective with the release of January 1998 data, BLS implemented a new composite estimation method for the Current Population Survey. The new technique provides increased operational simplicity for microdata users and allows optimization of compositing coefficients for different labor force categories. Under the new procedure, weights are derived for each record which, when aggregated, produce estimates consistent with those produced by the composite estimate. Under the previous procedure, composite estimate was performed at the macro level. The composite estimate for each tabulated cell was a function of aggregated weights for sample persons contributing to that cell in current and prior months. The different months of data were combined together using compositing coefficients. Thus, microdata users needed several months of CPS data to compute composite estimates. To ensure consistency, the same coefficients had to be used for all estimates. The values of the coefficients selected were much closer to optimal for unemployment than for employment or labor force totals. The new composite weighting method involves two steps: (1) the computation of composite estimates for the main labor force categories, classified by important demographic characteristics; and (2) the adjustment of the microdata weights, through a series of ratio adjustments, to agree with these composite estimates, thus incorporating the effect of composite estimate into the microdata weights. Under this procedure, the sum of the composite weights of all sampled persons in a particular labor force category equals the composite estimate of the level for that category. To produce a composite estimate for a particular month, a data user may simply access the microdata file for that month and compute a weighted sum. The new composite weighting approach also improves the accuracy of labor force estimates by using different compositing coefficients for different labor force categories. The weighting adjustment method assures additivity while allowing this variation in compositing coefficients.

Eight rotation panels for any given monthly CPS sample are approximately equal in size. Due to the 4−8−4 rotation pattern, six of these panels (about 75 percent of the sample) continue in sample the following month and one-half of the households in a given month's sample will be back in the sample for the same calendar month one year later. The sample overlap improves estimates of change over time. Through composite estimate, the positive correlation among CPS estimates for different months is increased. This increase in correlation improves the accuracy of monthly labor force estimates.

Bailar (1975) and Huang and Ernst (1981) introduced the concept of rotation bias. The CPS applied the method from Gurney and Daly (1965) by adding more weight in panels 1 and 5, leading to the form

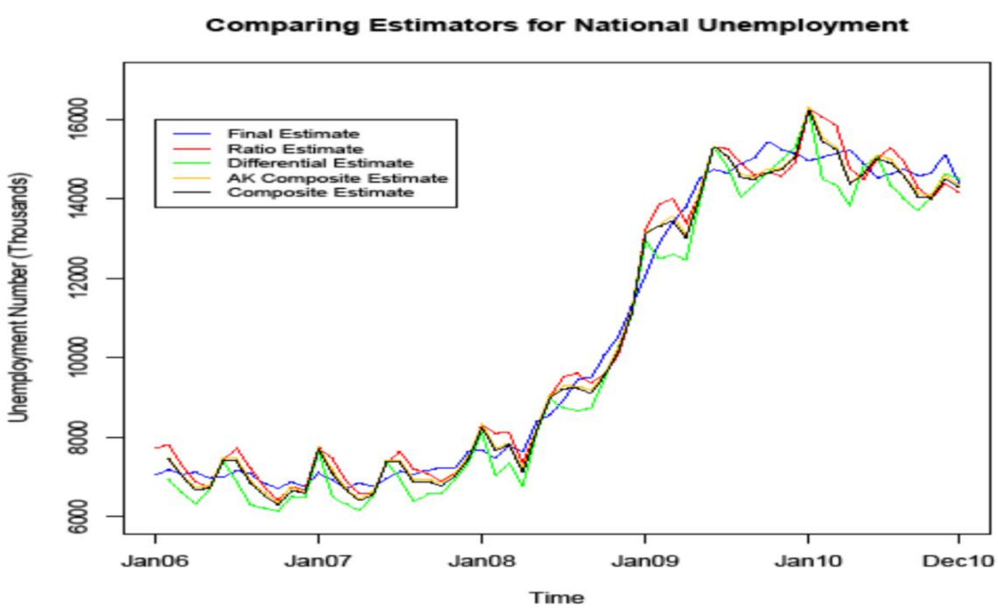
$$\frac{1}{8}\left\{\sum_{i\epsilon s^c}(1-K+A)\,\hat{Y}_{t,i}+\sum_{i\epsilon s}\left(1-K-\frac{1}{3}A\right)\hat{Y}_{t,i}\right\}+K\hat{Y}_t^2$$

Then, we have the AK composite estimate:

$$\hat{Y}_t^{AK} = (1-K)\hat{Y}_t^1 + K\hat{Y}_t^2 + A\hat{\beta}_t$$

where $\hat{\beta}_t = \frac{1}{8}\left(\sum_{i\epsilon s^c}\hat{Y}_{t,i} - \frac{1}{3}\sum_{i\epsilon s}\hat{Y}_{t,i}\right)$. Constants A and K are determined empirically. Note that $\hat{Y}_t^{AK}$ is a linear combination of terms $\hat{Y}_{t-h,i}$, $h = 0,\ 1,\ 2, \ldots$.

Figure 1: Comparison among different estimates for national unemployment



Currently, we use K = 0.4 and A = 0.3 when we estimate the number of unemployment. When we estimate the number employed, we choose K = 0.7 and A =0.4. The values given above for the constant coefficients A and K are close to optimal with respect to variance for month-to-month change estimates of unemployment level and employment level. The coefficient K determines the weight, in the weighted average, of each of two estimates for the current month: (1) the current month's Ratio Estimate $\hat{Y}_t^1$; and (2) the sum of the previous month's composite estimate $\hat{Y}_{t-1}$ and an estimate $\hat{\Delta}_t$ of the change since the previous month. The estimate of change is based on data from sampled households in the six panels common to months t and t-1. The coefficient A determines the weight of $\hat{\beta}_t$ an adjustment term that reduces both the variance of the composite estimate and the bias associated with time in sample (See Breau and Ernst, 1983, Bailar, 1975). Before January 1998, a single pair of values for K and A was used to produce all CPS composite estimates. Optimal values of the coefficients, however, depend on the correlation structure of the characteristic to be estimated. Research has shown, for example, higher values of K and A result in more reliable estimates for employment levels because the Ratio Estimates for employment are more strongly correlated across time than those for unemployment. The new composite weighting approach allows use of different compositing coefficients, thus improving the accuracy of labor force estimates, while ensuring the additivity of estimates. For a more detailed description of the selection of compositing parameters, see Lent et al.(1999).

Figure 1 shows the monthly numbers of unemployed from January 2006 to December 2010 when we applied Ratio Estimate, difference estimate, composite estimate, AK composite estimate, and seasonal adjustment. The seasonal adjustment part is done in the BLS after the Census finished AK composite estimate. The yellow line, the difference estimate, appears lower than other estimates do, and the red line, Ratio Estimate, stays higher. The two composite estimates are sitting between the red and yellow lines. The blue line, the final estimate (seasonal adjustment), smooth out high and low estimates month by month.

We have a few discussion points on possible research directions for CPS estimation. We talked about performing nonresponse adjustment, coverage adjustment, and calibration simultaneously. Next, we have information for 75 percent sample units at the unit level. Thus, we are able to compute the change over month at the unit level, and then calibrate for difference estimate. As we described above, the composite estimate is a linear combination of $\hat{Y}_{t-h,i},\ h = 0,\ 1,\ 2, \ldots$. We can develop a more general form for modifying composite estimate. Currently, we use fixed constant tuning parameters A & K. It should be possible to study and develop a data driven method to recalculate the tuning parameters A and K in AK composite estimate more frequently. Finally, it may be possible to derive new composite estimates by adjusting rotation bias.

4. Variance Estimator

CPS variance estimates take into account the magnitude of the sampling error as well as the effects of some nonsampling errors, such as response variance and intra-interviewer correlation. Replication methods are able to provide satisfactory estimates of variance for a wide variety of designs using probability sampling, even when complex estimation procedures are used. Prior to the 1980 design, variances were computed using Fay Method Balanced Repeated Replication (BRR). The sample was divided to form 48 replicates that retained all the features of the sample design, for example, the stratification and the within PSU sample selection. For the NSR PSUs, pairs and triplets of strata have been grouped into collapsed strata within each state. In the case of two PSUs in a collapsed stratum, a single degree of freedom for the collapsed stratum is obtained by contrasting the two PSU level estimates using a modified half-sample technique. By using orthogonal contrasts, two degrees of freedom are obtained from each triplet. For SR PSUs, the segments in each SR PSU were systematically divided into 2 half samples in an attempt to capture the effect of systematic sampling on the variances.

Let K denote strata and S_{kH} be the split half-samples, for H = 1, 2. Then $\hat{Y}$ is defined through estimates $\hat{Y}_{kH}$ of half-sample totals as

$$\hat{Y} = \sum_{k,H} W_k \sum_{i \epsilon S_{kH}} w_i y_i = \sum_{k,H} W_k \hat{Y}_{kH}$$

The Hadamard coefficients used to produce the half-sample replicate weights satisfy the following conditions:

$$a_{rk} = \pm 1 , \sum_{r=1}^{R} a_{rk} = \sum_{r=1}^{R} a_{rj} a_{rk} = 0 , j \neq k$$

For r = 1, …, R, the Fay method replicate weights are

$$w_i^{(r)} = w_i(1 + \varepsilon(-1)^{H-1} a_{rk})$$

where ε is fixed number between 0 and 1, usually $1/2$. Then, the r'th replicate estimate of Y is:

$$\hat{Y}^{(r)} = \sum_{k,H} W_k \sum_{i \epsilon S_{kH}} w_i^{(r)} y_i = \hat{Y} + \varepsilon \sum_{k} W_k a_{rk} \left(\hat{Y}_{k1} - \hat{Y}_{k2}\right)$$

Fay's BRR variance estimator is:

$$\hat{V}_{BRR} = \varepsilon^{-2} R^{-1} \sum_{r=1}^{R} \left(\hat{Y}^{(r)} - \hat{Y}\right)^2 = \sum_{k=1}^{K} W_k^2 \left(\hat{Y}_{k1} - \hat{Y}_{k2}\right)^2$$

Note that Fay created alternative ± 1 designs making $\hat{V}_{BRR}$ approximately design consistent for $V\left(\hat{Y}\right)$. Krewski and Rao (1981) showed that design consistency for BBR variance estimates happens generally only when the degree of freedom K goes to infinity.

Wolter (1985) provided a form of successive difference (SD) method variance estimator of a total from a systematic sample through the quadratic form based on squared differences between neighboring sample cases

$$\hat{V}_{SD}\left(\hat{Y}\right) = (1 - f) \frac{n}{2(n-1)} \sum_{i=2}^{n} (\hat{y}_i - \hat{y}_{i-1})^2$$

where $\hat{y}_i$, $i = 1, 2, \ldots$, n, represents a series of ordered estimates, and f denotes the sampling fraction.

Fay and Train (1995) proposed a successive difference replication (SDR) variance estimate. They define the estimate for each replicate total as

$$\hat{Y}^{(r)} = \sum_{i=1}^{n} f_{i,r}\hat{y}_i$$

where the replicate factor for each $\hat{y}_i$ is

$$f_{ir} = 1 + (2)^{-3/2}a_{i+1,r} - (2)^{-3/2}a_{i+2,r}$$

Then, the SDR variance estimator is

$$\hat{V}_{SDR}(\hat{Y}) = 4\,(4k)^{-1}(1-f)\sum_{r=1}^{4k}\left(\hat{Y}^{(r)} - \hat{Y}\right)^2$$

Note that $\hat{V}_{SDR}(\hat{Y})$ is approximately equivalent to the modified version of SD variance estimator and $f_{i,r}$ is 1 or $1 \pm \frac{1}{\sqrt{2}}$.

Strictly speaking, the variance estimator is not unbiased for simple random samples, but Monte Carlo studies suggest a small bias, less than 1 percent, even for relatively small n. The convenience of this SDR approach arises from the ability to assign new units to the end of the chain. Also, it is easy to implement.

5. Future Research

The broad goal of future research is to evaluate existing statistical estimation methodologies used to produce various unemployment rate statistics and explore if some of the most promising recent research in this general area can be adapted to improve the current estimation system. There are several specific ideas:

The parameters A and K in the AK composite estimate $\hat{Y}_t^{AK}$ can be viewed as tuning parameters and determined empirically. According to Technical Paper 66 of U.S. Census (2006), K = 0.4 and A = 0.3 for unemployment, and K = 0.7 and A = 0.4 for employment, were derived based on some empirical studies on minimizing the variances of change estimates. However, we feel that the optimal values of K and A determined about 25 years ago may not be suitable for current estimation. In fact, these tuning parameters should be updated in a much shorter period of time. We propose to study how to determine tuning parameters in AK composite estimates or the proposed new BK composite estimates. It requires the derivation of an approximate variance formula for the AK or BK composite estimates. Alternatively, replication methods such as the balanced half samples and bootstrap can also be studied. A related issue is whether we should find tuning parameters by minimizing the variances of change estimates or minimizing the mean squared error of monthly total estimates.

Develop a general calibration estimation technique to produce a class of composite estimates of unemployment rates and compare the most promising new composite estimates with the well-known AK composite estimate currently used to estimate unemployment rates for the nation, state, and substate area.

Develop single set of bootstrap replicate weights for multi-purpose inferential purposes. Compare the variance estimates and the associated confidence intervals generated by these bootstrap weights with the current variance estimation method used in the CPS unemployment rate estimation program.

Develop a hierarchical Bayesian methodology for producing unemployment rate statistics for small domains by combining information from the CPS historical series along with available administrative data. Combining information from multiple sources is likely to enhance estimation or may be necessary due to the cost and infeasibility of collecting new data.

Acknowledgements

I would like to thank Ruth Ann Killion and Patrick Flanagan of Demographic Statistical Methods Division at the U.S. Census Bureau for serving as reviewer as well as Dr. Partha Lahiri from the Center of Statistical Research and Methodology (CSRM) of the U.S. Census Bureau and the University of Maryland. Also, thanks to Dr. Eric Slud of CSRM and Dr. Jun Shao from the University of Wisconsin-Madison for useful suggestions and comments.

References

Bailar, B.A., (1975). The Effects of Rotation Group Bias on Estimates from Panel Surveys. Journal of the American Statistical Association, 70, 23-30.

Breau, P., Ernst, L., (1983). Alternative Estimators to the Current Composite Estimator. Proceedings of the Section on Survey Research Methods, American Statistical Association, 397-402.

Fay, R., Train, G., (1995). Aspects of Survey and Model-Based Postcensal Estimation of Income and Poverty Characteristics for States and Counties, Proceedings of the Section on Government Statistics, American Statistical Association, 154−159.

Gambino, J.G., Do Nascimento Silva, P.L., (2009). Sample and Estimation in Household Surveys, Essential Methods for Design Based Sample Surveys, 1st Edition, North Holland, 97-129.

Gurney, M., Daly, J.F., (1965). A Multivariate Approach to Estimation in Periodic Sample Surveys. Proceedings of the Social Statistics Section, American Statistical Association, 242-257.

Hansen, M.H., Hurwitz, W.H., Madow, W.G., (1953). Sample Survey Methods and Theory, Vol. II, New York: John Wiley and Sons.

Hansen, M.H., Hurwitz, W.N., Nisselson H., Steinberg, J., (1955). The Redesign of the Census Current Population Survey. Journal of the American Statistical Association, 50, 701-719.

Huang, E.T., Ernst, L.R., (1981). Comparison of an Alternative Estimation to the Current Composite Estimator in CPS. Proceedings of the Section on Survey Research Methods, American Statistical Association, 303-308.

Krewski, D., Rao, J.N.K., (1981). Inference from Stratified Samples: Properties of the Linearization, Jackknife and Balanced Repeated Replication Methods. Annals of Statistics, Volume 9, Number 5, 1010-1019.

Lent, J., Miller, S.M., Cantwell, P.J., (1994). Composite Weights for the Current Population Survey, Proceedings of the Survey Research Methods Section, American Statistical Association, 867−872.

Lent, J., Miller, S.M., Cantwell, P.J., and Du, M., (1999). Effect of Composite Weights on some Estimates from the Current Population Survey. Journal of Official Statistics, 14, 431-448.

Wolter, K.M., (1979). Composite Estimation in Finite Populations. Journal of the American Statistical Association, 74, 604-613.

Wolter, K.M., (1985). Introduction to Variance Estimation, New York: Spring-Verlag.

U.S. Census Bureau, (2006). Design and Methodology: Current Population Survey, Technical Paper 66, October 2006, http://www.census.gov/prod/2006pubs/tp-66.pdf.