EVALUATION OF ESTIMATORS FOR EMPLOYMENT LEVEL AND CHANGE IN ESTABLISHMENT SURVEYS

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1. INTRODUCTION

The Bureau of Labor Statistics' (BLS) Current Employment Statistics Survey (CES) is a monthly survey of over 275,000 nonagricultural business establishments from which estimates of total employment, women and production workers, hours, and earnings are produced. Estimates are made for over 500 industries, complementing the demographic detail provided by estimates of employment from the Current Population Survey. Of primary interest to users are the estimates of monthly employment level and the employment change from the previous month. Additionally, each state conducts a complete count of the employment of its business population every quarter under the guidelines of its unemployment insurance (UI) system. Except for a few industries exempt from UI coverage, this complete count is used by the CES as a benchmark to which survey estimates are revised, and also provides a measure of survey error.

In this paper, ratio, regression, and Horvitz-Thompson estimators of employment level and change in a number of industries are evaluated using population data obtained from the UI system and survey data collected by the CES survey. Using repeated sampling of the UI population, the bias, variance, and mean square error of the estimators are derived. Using CES survey data, the research is expanded to include the effect of nonresponse, business births and deaths, and the treatment of "outliers" or atypical reporters. Properties and limitations of the CES survey and the UI population data are compared in order to explain differences between the two studies.

The Current Employment Statistics Survey design and estimation procedures and the UI benchmark procedures are detailed in Section 2 of this paper. The research methodology and results from the study of the UI population are presented in Section 3. The research methodology and results from the study using the CES survey data are provided in Section 4, and the two sets of results are compared in Section 5. Results and conclusions are summarized in Section 6.

2. CURRENT EMPLOYMENT STATISTICS SURVEY

The Current Employment Statistics Survey is a monthly voluntary survey of business establishments. Data on the number of total employees, women workers, production workers, hours, and earnings are collected from sample establishments on a mail shuttle schedule which is edited and keypunched by the state cooperating agencies and sent to BLS in Washington. The survey is used to determine the change in employment each month, with employment level determined once a year from the complete count, or benchmark, of businesses conducted by the states' unemployment insurance system.

The frame for the CES survey consists of a list of all business establishments compiled by BLS from the states' UI systems. The sample design is highly stratified by industry and employment, with estimates generally produced at the three or four digit Standard Industrial Classification (SIC) level. Sample sizes are specified for six employment size classes within an industry.

The survey uses a link relative estimator, with the current month's employment estimate equal to the previous month's estimate multiplied by the sample ratio, or link, of current to previous month's employment. The number of estimation cells varies across industries. For many industries, a link is computed for as many as five employment size classes within the industry, while for others, only one link is computed. Each of the estimation cells is benchmarked annually.

Another component of the estimate consists of atypical reporters. Atypical reporters are not used in calculating the ratio of employment change, but are added to the estimates with weight one, representing only themselves.

To be used in calculating the ratio of employment change or to be considered atypical, a sample unit must respond in two consecutive months so that its current and previous month employments are known. Using the matched sample technique lowers the variance of the estimates since an establishment's employment from month to month is highly correlated. The disadvantage is that the usable sample size is decreased since data for establishments responding in only a single month are not used in the estimates.

For a given month, estimates are published in a series of three monthly releases, referred to in this paper as first, second, and third closing estimates. For example, employment estimates for June are first published in a preliminary form (first closing estimates) in early July based upon the respondents collected to that date. Another preliminary estimate for June is published in early August based upon a larger set of respondents (second closing estimates). The final estimate is published at the beginning of September based upon the full set of respondents to that date (third closing estimates). The third closing estimates may be revised when a benchmark becomes available. Monthly employment change estimates are also published in three releases. The May to June employment change is first estimated as the difference between the first closing June level estimate and the second closing May level estimate. The second closing estimate of the change is equal to the difference between the second closing June level estimate and the third closing May level estimate. The third closing estimate of the change is the difference between the third closing level estimates for May and June. Hence, differences between the preliminary and final level estimates affect the monthly change estimates as well. Employment characteristic differences between preliminary and final respondents account for part of the discrepancy, as well as nonresponse characteristics of the estimators. In this research, the difference between preliminary and final estimates for various estimators is compared.

The purpose of a state's unemployment insurance system is the collection of UI taxes, and to accomplish this a large data base on business establishments is maintained and periodically updated. Individual state UI systems and laws differ, but in general, every business within a state meeting some minimum employment and wage criteria must report its monthly employment and quarterly wages to the state at the end of every calendar quarter. An auxiliary use of this data base is the compilation of the complete count of business employment for the CES and individual state estimates. For the CES benchmark reference period, March, employment data are collected by the state in the second and third quarters of the year and then sent to BLS. The national employment benchmark is computed at industry and employment size class levels and published in June of the following year, fifteen months after the reference period. The survey estimates for the benchmark month are revised to agree with the benchmark, and estimates produced since the preceding benchmark are revised if necessary.

The amount of the revision represents the estimator's bias accumulated in the year since the previous benchmark. For the link relative estimator used in the survey, the current month's employment estimate is essentially the benchmark multiplied by the product of the monthly links. Because of the long benchmark preparation schedule, between 12 and 25 links are needed to make an estimate, each contributing to the bias and variance.

Other sources contributing to survey error include survey noncoverage of business births and deaths, and a lack of agreement between sampling cells and estimation cells. Because of the difficulty in the timely identification of business births and deaths and their inclusion in the sample, the survey estimates don't reflect their employment impact which, however, is measured in the benchmark. Additionally, an estimation cell is often an aggregation of sampling cells, but no weighting procedure is used when computing the ratio. The result is that large sample units dominate the estimate and a differential growth rate between small, medium, and large establishments will produce a bias in the estimate.

A goal of this research is the understanding of the theoretical and empirical CES bias and variance properties of ratio, regression, and Horvitz-Thompson estimators of employment level and change. The theoretical properties of the estimators were determined in a study using establishment microdata obtained from the unemployment insurance system.

3. ESTIMATOR ANALYSIS USING UNEMPLOYMENT INSURANCE POPULATION MICRODATA

This phase of research into CES estimators investigated the variance and bias properties of six different estimators of total employment by industry. The investigation involved an empirical study using independently drawn samples from the full UI population of business establishments, evaluating the performance of the estimators over a 25 month period (the current CES time frame).

The primary objectives of this phase of the investigation were to: (1) confirm the known properties of the estimators and the relationships between estimators; (2) analyze the performance of the estimators over a wider range of industries and a longer time frame than had been studied previously at BLS; and (3) analyze the variance and bias properties of the estimators relative to the characteristics of the population distribution.

Methodology

Six different estimators were used to estimate total employment level and monthly employment change. Five of the estimators were link relative estimators, and the sixth estimator was the Horvitz-Thompson estimator. The estimators are described in Section 4. Because of limitations associated with the use of the UI data, the regression estimators that are evaluated using CES survey data could not be studied in this phase.

For the analysis, seven industries were subjectively chosen to provide a range of industry average employment, total employment, number of establishments, and sample size. High average employment and CES sample coverage occur in Manufacturing and Hospitals. Low average employment and sample coverage occur in the Construction, Trade, and Finance industries. Average employment ranges from 9 in SIC 543 to 589 in SIC 806. The percentage of establishments covered in the sample ranges from 2 in SIC 543 to 43 in SIC 22.

Only establishments reporting employment to the state unemployment insurance agencies in March 1982, March 1983, and January, February, and March 1984 were eligible for inclusion in the study. This study did not, therefore, include any births or deaths, nor did it include any establishments which were nonrespondents in any of the months used for the study.

Based on their March 1982 employment, establishments were classified into the BLS nine standard size classes containing 1-3, 4-9, 10-19, 20-49, 50-99, 100-249, 250-499, 500-599, and 1000 or more employees. The sample size for each industry was the number of establishments collected in the CES survey in March 1984. The two largest size classes were sampled with certainty and the optimal allocation for the Horvitz-Thompson estimator was used to divide the remaining sample among the small and medium size classes. In cases where no sample was optimally allocated to a size class, a single establishment was sampled. This occurred in size class seven in SIC 543 and size classes one through three in SIC 806.

For each industry, March 1982 employment was used as the benchmark employment. A sample of units was drawn independently in each size class using a uniform random number generator, and employment for March 1983 and January, February, and March 1984 was estimated using each of the six estimators. One thousand samples were randomly chosen. Since only data for the first quarter of the year were available, nonresponse could not be simulated.

For each estimator the relative bias, relative standard error, relative mean square error, and maximum bias for predicting employment level were estimated, based on the one thousand samples and the known population employment totals. For predicting the employment change from January to February and February to March 1984, the bias and MSE were estimated.

Results

Relative Bias -- The relative bias for March 1983 was estimated and compared against the average of the January, February, and March 1984 relative biases. The relative bias represents the difference that could be expected between the estimates and the benchmark. Almost all the biases are negative, with the exception of SIC 543. In six of the seven industries, the estimators HT, WLR, and SLR have almost no bias in either year. The estimator WLR2 has some bias in SICs 176 and 616, but otherwise performs very well. Estimator MWLR has a somewhat larger bias since underestimation in the smaller size classes is not balanced by overestimation in the larger size classes. Estimator ULR has an appreciable bias in five of the seven industries, ranging from 1 percent to 10 percent.

Comparing the relative bias from 1983 and 1984, the HT, WLR, and SLR estimators show very little change in five of the seven industries. In SICs 543 and 616 their bias does increase but is still less than 0.35 percent in 1984. For the other three estimators the relative bias of each estimator increases between 1983 and 1984, but most of the bias is generated in the first year after the benchmark - March 1982 to March 1983. A notable exception to this occurs in SIC 543, especially for estimator ULR. Here the sample is concentrated in establishments with benchmark employment between 50 and 500 employees. These establishments had a much greater rate of employment increase between March 1983 and March 1984 than the smaller establishments. Since the ULR estimator does not use sampling weights, a large positive bias occurred.

For each industry and estimator, the maximum of the relative biases was determined. This measure indicates the worst an estimator might do in any particular month. Estimator ULR has the potential for very large biases in five of the seven industries, ranging from 2 percent to 10 percent. Estimators MWLR and WLR2 also have large biases, up to 3.4 percent, in a few industries, but outperform ULR in all industries. The maximum relative bias for HT, WLR, and SLR is very small in all industries with a magnitude always less than 0.5 percent. For ULR, MWLR, and WLR2, the maximum relative bias almost always occurs in March 1984, the month farthest from the benchmark. For the other three estimators, the monthly biases are roughly equal and the maximum relative bias can occur in any of the four months.

Relative Standard Error -- In all but one industry, SIC 543, estimator ULR has the smallest relative standard error because it does not employ sampling weights. Estimator MWLR, which does have sampling weights, has a relative standard error slightly greater than that for ULR. Estimators HT, WLR, and SLR perform identically and, as expected, estimator WLR2 has a smaller relative standard error than WLR, but not as small as MWLR.

Relative Mean Square Error -- The relative mean square error for January, February, and March 1984 were averaged and compared to the relative MSE in March 1983. Since the estimators HT, WLR, and SLR are virtually unbiased, their relative MSE is essentially their relative standard error. Estimator ULR has a small variance, so its relative MSE is close to its relative bias. Estimators MWLR and WLR2 were formulated as improvements to WLR. They tend to have a smaller variance and larger bias than WLR and so their MSE can be greater than or less than the MSE for WLR.

In all industries except SIC 806, estimators WLR and SLR have the smallest MSE. The MSE for estimator HT is slightly higher. Estimator WLR2 performs as well as WLR and SLR in all but SIC 176, and there only marginally worse. Because of its bias potential, estimator MWLR does not perform as well as WLR, except in SIC 806 where it had the smallest MSE. Despite its small relative standard error, estimator ULR performs poorly in industries in which it has a large bias. In general, across industries and estimators, the relative MSE in 1984 is twenty to fifty percent greater than the relative MSE in 1983.

Bias and MSE for Predicting Employment Change -- Estimators HT, WLR, and SLR again perform similarly and have relatively small bias. Estimator WLR2 performs almost as well, except in SICs 176 and 22. Estimators ULR and MWLR have relatively large bias in all but two SICs. Most interestingly, for estimators HT, WLR, and SLR, their large variance overwhelms the actual employment change in SICs 176, 543, and 616, the three industries with low sample coverage. In general, estimator WLR2 has a slightly smaller root MSE than HT, WLR, and SLR. Estimators ULR and MWLR have higher root MSEs due to their large biases.

4. ESTIMATOR ANALYSIS USING CES SURVEY DATA

This area of research into CES estimators expands the research in the UI study phase reported in Section 3. Again, the bias and variance properties of various estimators of total employment for the seven industries are investigated. In this phase, however, an empirical study is carried out using actual CES survey data. This allows the impact of births, deaths, nonresponse, and atypicals to be included in the analysis of the performance of the estimators. In addition, the number of estimators being investigated has been expanded.

The primary objectives of this phase of the estimator research are to: (1) analyze the performance of the estimators on actual survey data; (2) compare the performance of the estimators on the full population data (from the previous phase of research) to their performance using the survey data; and (3) analyze the effect of sample data characteristics on estimator performance.

Estimators

The five link relative estimators and the Horvitz-Thompson estimator investigated in the research using the UI population data are also used in the analysis for this phase of CES estimator research. In addition, two regression estimators, a weighted link relative estimator using employment weights instead of unit count weights, and a difference estimator are included in this study. The first six estimators described below are used in both the UI study phase and the CES study phase.

The first estimator, which closely resembles the current CES estimator, is the unweighted link relative estimator (ULR). Here only one link is calculated in each industry. This estimator ignores the size class stratification and sampling weights.

The second estimator is a weighted link relative estimator (WLR). This estimator employs sampling weights based on size class unit counts when calculating the link.

The third estimator is a modified weighted link relative estimator (MWLR) which consists of two components: 1) the known sample total employment, and 2) an estimate of the non-sample total employment based on the WLR. Since the known sample total does not have to be estimated, as it is in the previous estimators, this estimator is expected to have a smaller variance than the WLR estimator.

The fourth estimator is a separate link relative estimator (SLR). A link and employment estimate is computed for each size class within an industry. This estimator performs well when the links differ across size classes. However, the bias of the total employment estimates can be large if the size class estimates are biased in the same direction.

The fifth estimator is a weighted link relative estimator with two estimation cells (WLR2). Based on previous results, it was believed that the variance of the WLR estimator could be reduced by making estimates for the certainty and noncertainty strata separately. This estimator uses the matched sample data from the noncertainty strata and the estimator WLR to estimate total employment for the noncertainty strata, and then adds on the certainty strata sample total. Since the certainty strata employment does not have to be estimated, it will not contribute to the bias or variance of the estimator. In the CES phase of research, when there is nonresponse in the certainty strata, total employment for the certainty strata is estimated using the WLR estimator and the certainty strata respondents.

The Horvitz-Thompson estimator (HT) inflates the current sample employment in each size class by the sampling weight. Since only the current sample is used, the relation between current and previous employment is ignored. However, in the CES study phase, the usable sample size is increased since an establishment need only respond for the current month and not for two consecutive months as is the case for the other estimators.

For the research phase using the CES survey data, the following four estimators were also evaluated.

The first estimator is a separate regression estimator (SR). Regression coefficients are estimated for each size class within an industry.

The second estimator is a combined regression estimator (CR). Using size class sample weights, one regression coefficient is estimated for an industry.

Because of the skewness in sample average employment observed in some industries, a sixth weighted link relative estimator (EWLR), using size class employment weights instead of unit count weights, was developed. Only one link is computed for an industry.

In contrast to the link relative estimators, which use the ratio of the sample current and previous month employments to adjust the previous month's estimate, the difference estimator (DL) obtains the estimate for the current month by adding an estimate of change to the previous month's estimate. This estimate of change is based on the difference in employment from one month to the next for the establishments reporting in both months.

Methodology

The same seven industries used in the UI study phase of research are used in the CES study phase in order to provide a base of comparison of the full population results to the results for the survey data.

For each industry, the March 1982 UI benchmark employment is used as the starting point for estimation. Employment level and monthly change estimates are made using all of the estimators described above and CES survey data for the period March 1982 through March 1984. The estimates are made in a series of three closings as described in Section 2.

Since population data are not available on a monthly basis, the bias of the employment level and monthly change estimates cannot be determined for each month. However, there are several measurements which are made to evaluate the performance of the estimators: 1) the bias of the estimators, based on comparison to the March 1983 and March 1984 UI benchmarks; 2) the sizes of the differences in employment level estimates between first and second, second and third, and first and third closings; 3) the sizes of the differences in the monthly change estimates between closings.

Results

Relative Bias -- The relative bias for each estimator within each industry was estimated for March 1983 and March 1984. The estimated relative bias is the difference between the March estimate and benchmark, relative to the March 1982 benchmark. General results obtained are: (1) there is no estimator which consistently performs well across industries for March 1983 and March 1984, and (2) with few exceptions, the relative bias for an estimator within an industry increases from March 1983 to March 1984.

The absolute relative bias for an estimator within an industry generally increases from March 1983 to March 1984 anywhere from less than one up to 15 percentage points. The ULR, HT, and DL estimators each have several instances of reductions in the absolute relative bias. For the ULR and DL estimators the reductions are less than 2 percentage points. The reductions in absolute relative bias for the HT estimator are 10 to 20 percentage points, but the March 1984 relative bias is still greater than 30 percent in those industries.

Each estimator has a small absolute relative bias for SIC 806. This industry has a very high average employment (almost 600 employees) and the population is heavily skewed toward large units (88 percent of the units have 100 or more employees). Each estimator has a high absolute relative bias for SIC 616. This industry had very large growth in both number of population units and employment from March 1982 to March 1984 (30 percent growth in number of population units, 30 percent growth in average employment and 70 percent growth in total employment).

The ULR estimator tends to have smaller absolute relative biases in the industries where the population is skewed toward large units, and larger absolute relative biases in the industries where the population is skewed toward small units.

The estimators WLR and WLR2 have virtually identical relative biases across industry in both March 1983 and March 1984. These estimators tend to have smaller absolute relative biases (less than 10 percent) in industries which had negative or small employment growth and larger absolute relative biases (greater than 10 percent) in industries which had large employment growth.

The SLR estimator also tends to have smaller absolute relative biases in industries with negative or small employment growth, and larger absolute relative biases in industries with large employment growth. In general, however, the WLR and WLR2 estimators have smaller absolute relative biases.

The HT estimator has a small absolute relative bias only in SIC 806, while for all other industries it has large absolute relative biases.

The SR and CR estimators have virtually identical relative biases across industry in both March 1983 and March 1984 (with the exception of SIC 543 in March 1983). These estimators tend to have smaller absolute relative biases in industries with large average employment and larger absolute relative biases in the industries with small average employment. In this regard they are similar to the ULR estimator, although the ULR estimator has smaller absolute relative biases than the SR and CR estimators in almost every instance.

The EWLR estimator tends to have smaller absolute relative biases in those industries with negative or small employment growth, and to have slightly larger absolute relative biases in those industries which had large employment growth. Its performance is similar to the estimators WLR, WLR2, and SLR.

The DL estimator also tends to have smaller absolute relative biases in those industries with negative or small employment growth, and larger absolute relative biases in those industries with large employment growth.

Difference Between Closing Estimates -- In general, level estimates are more different between closings than estimates of change, with the differences usually less than one percent of the benchmark employment. Estimator ULR performs best for both level and change, followed by estimators SLR and EWLR. The two regression estimators, SR and CR, perform similarly, both slightly worse than EWLR. The two weighted link relative estimators, WLR and WLR2, also perform similarly, with differences near those for SR and CR. Estimator DL has about 50 percent greater differences between closings than ULR, but they are still usually less than 1.5 percent of total employment. The Horvitz-Thompson estimator performs poorly due to changes in average employment of respondents between closings.

The estimators are at their worst in SIC 543, the industry with small establishments and low sample coverage, with ULR having differences near 3 percent of the benchmark. The estimators perform best in SIC 806 which is characterized by large establishments and high sample coverage.

Across industries, the difference between the first and third closing estimates is 10 to 20 percent greater than the difference between the first and second closing estimate of both level and change. The differences do not increase month after month uniformly across industries. In SICs 176, 371, and 616, the average differences for April 1982 through March 1983 are smaller and of the opposite sign than those in April 1983 through March 1984. In SICs 22, 33, and 543, the situation is reversed and, on average, the direction of the differences are the same between the two time periods.

5. COMPARISON OF RESULTS

The relative bias of the estimators was analyzed in both studies. There are similarities in the results from the two analyses, primarily in the relative performance of the estimators, but there are also some differences requiring explanation. Perhaps the most striking difference is the performance of the HT estimator. In addition, the size of the absolute relative biases are larger under the CES sample data.

Given the method of selection and the assumption of 100% response for the UI population microdata, the HT estimator is theoretically unbiased, and the results show that the relative bias for the HT estimator is very close to zero across industries. However, the sample for the CES survey is not selected with probability n/N (as is assumed for the HT estimator), nor are responses obtained from all sample units. The HT estimator can therefore result in large biases if the probability of selection within size class is much different from n/N, or if the distribution of respondents within size class is skewed. This is the situation for the industries where the HT estimator has large absolute relative biases (176, 33, and 543).

The estimators WLR, WLR2, and SLR perform similarly within each analysis. The absolute relative biases, however, are much larger under the CES survey data for some SICs (176, 371, 543, and 616). For three of these industries --

176, 543, and 616 -- the relative biases seem to be the result of the growth in number of units within the SIC, rather than any inadequacies in the estimators. The sample for the CES survey does not reflect new establishments ("births") from 1982 to 1984, but the benchmark employment does. If the benchmark employment for 1984 is adjusted for the growth in population size, the relative biases for the WLR, WLR2, and SLR estimators would be very close to zero. It thus appears that these estimators do estimate the change in employment for the population which was in existence throughout the time period. What these estimators do not do is estimate the change in employment due to changes in the number of population units. For SIC 371, the relative biases for the WLR, WLR2, and SLR estimators do not appear to be due to births. Reasons for the large relative biases are still being investigated.

The performance of the ULR estimator is much the same under the two analyses, especially after adjusting for the growth in the population sizes. The ULR estimator does not perform well for industries where the population is skewed toward small units (176 and 543).

6. SUMMARY

In this paper, the results from two studies of estimator performance in the Current Employment Statistics Survey are presented and compared. The first study used establishment employment reported to the state unemployment insurance systems as the population, and the theoretical bias and standard error of the estimators were predicted by choosing one thousand random samples from the population. In the second study, CES survey data were used in calculating estimates, which were compared against benchmark employment levels determined from UI data.

Results from the UI population study confirm the theoretical properties of the estimators. The Horvitz-Thompson, weighted and separate link relative estimators are virtually unbiased, while the unweighted link relative estimator has the potential for large bias due to its lack of sampling weights. For the same reason, ULR has the smallest standard error among the estimators.

The employment of establishments in a size class becomes more variable farther from the benchmark, and the results quantify the increase in bias and standard error of the estimators between March 1983 and 1984.

On first inspection of the results from the study using CES survey data, the three previously unbiased estimators perform poorly in some of the industries. Further examination of the sample data and benchmarks indicate that business births and deaths, which are measured in the benchmark but not in the sample, contribute to the bias of the estimators. Additionally, respondents moving in and out of the matched sample affect the estimates. The bias in a month's estimate is further propagated by the ensuing links, as evidenced by the increase in bias from March 1983 to March 1984.

For all estimators except the Horvitz-Thompson, the difference between closings was uniform across industries, due to the use of the matched sample and the previous month's employment in estimation. For the HT estimator, which is based on the average employment of the sample, employment differences in the respondents to the different closings generate large discrepancies between first, second, and third closing estimates.

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