ADJUSTING THE 1993 COMMODITY FLOW SURVEY TO THE 1992 ECONOMIC CENSUS

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1. INTRODUCTION

The Bureau of the Census designed the 1993 Commodity Flow Survey (CFS) to provide data on the flow of goods and materials by mode(s) of transport. The chief goal was to measure the total value, weight, and distance traveled of shipments in all trade areas according to origin of shipment, destination, commodity shipped, mode or modes of transportation, and several other characteristics. The target population for the CFS was all shippers active in 1993.

Sampling was done in three stages. First, about 200,000 establishments were selected. Then, for each sample establishment, a two-week reporting period was designated for each quarter of 1993. Finally, each establishment was asked to select a sample of shipments from all those made during its two-week periods.

To produce an estimate of total for a specific variable, one could simply inflate the reported values using the appropriate probabilities of selection, making adjustments to the weights for nonresponse at each stage of sampling. However, due to the unusual sampling scheme, the resulting weights would be highly variable across all shipments, which would tend to create undesirably high variances. In many cases, response errors have also hindered our ability to determine proper sampling weights and have introduced bias into the estimates. In addition, the issue of adjusting for establishment nonresponse is complicated by our lack of information about nonrespondents and about new establishments which began operations after the sample had already been selected.

With these issues in mind, we decided to adjust the estimates using data from the 1992 Economic Censuses. The Census data were projected upwards (or downwards) for growth to 1993, the year the CFS was conducted. The Census and the CFS were linked by the variable "value of shipments." In adjusting the sampling weights by the ratio of Census value of shipments to CFS, estimates of *all other characteristics* --- tons, ton-miles, etc. --- *were increased or decreased proportionately*. Thus we hoped to stabilize all survey estimates through the adjustment process.

In this paper, we discuss in greater detail the motives for our adjustment decisions and some of the early results. We provide general background on the CFS and summarize the design of the survey in Section 2. Weighting and nonresponse adjustments are described in Section 3. Sections 4, 5, and 6 are the focus of the paper. Here we present and discuss the census adjustments applied to the CFS weights, we review the distribution of the adjustment factors, and we evaluate the overall adjustment procedure in terms of its effect on the estimates. Section 7 summarizes our findings and suggests improvements for future versions of the CFS.

2. SURVEY DESIGN

The purpose of the 1993 CFS was to measure the domestic flow of goods during the calendar year 1993. The sampling frame was constructed to include establishments that would likely be engaged in shipping. To this end, the frame included all establishments classified in the mining, manufacturing and wholesale trade areas. It also included establishments in a few selected kinds of business in the retail (catalog and mail-order houses) and service (videotape wholesalers) trade areas that were thought to be potential shippers.

The source of the frame was the 1992 Standard Statistical Establishment List (SSEL) of business establishments with paid employees, maintained by the Census Bureau. Establishments in the appropriate trade areas that had nonzero payroll in at least one quarter of 1991 were included in the frame. The inscope universe contained approximately 800,000 establishments.

The CFS sample derives from a stratified design which selected units in three stages: establishments, two-week periods (one in each quarter of the year), and shipments within the two-week period. Before selecting the sample, we stratified establishments in the frame by

[1] This paper reports the general results of research undertaken by Census Bureau staff. The views expressed are attributable to the authors and do not necessarily reflect those of the Census Bureau.

3-digit SIC × NTAR. The SIC (Standard Industrial Classification) code classifies establishments according to their predominant commodity produced or sold. The NTAR (National Transportation Analysis Region) distinguishes the geography of the shipper. The 89 NTARs were developed by the Department of Transportation and constitute a mutually exclusive and exhaustive partition of the entire United States.

We selected large establishments with probability one, and a sample of smaller establishments with probability generally proportional to the establishment's annualized payroll. The final sample contained just under 200,000 establishments in all.

In the second stage of sampling, each selected establishment was assigned four two-week reporting periods, one in each quarter of 1993. To guard against quarterly cycles, the periods were assigned so that an establishment did not report at the same time in each quarter.

For the final stage of sampling, we asked each sampled establishment to select a systematic sample of shipments from their files for each of the four reporting periods, based on the total number of shipments the establishment made in the period. For each of the sampled shipments, respondents were asked to report origin, destination, weight, value, major commodity shipped, modes of transport, and several other characteristics.

For more background information on the purpose of the CFS, the survey design, and sample selection, see Smith, Evans, and Fowler (1994).

3. WEIGHTING AND NONRESPONSE

Each CFS sample shipment has associated with it a single CFS weight, which is used with the shipment in computing all estimates to which the shipment contributes. Before considering nonresponse, the CFS weight is simply the product of three weights, each one following from one of the stages of sampling. The three components are

- the *establishment weight:* the reciprocal of the inclusion probability for the establishment;
- the *quarter weight:* equal to 13/2 for all shipments from all establishments (two weeks representing the 13-week quarter); and
- the *shipment weight:* calculated separately for each establishment and for each quarter. It equals the ratio of the total number of shipments made in the two-week reporting period (for that quarter) to the number of shipments sampled by the respondent.

The CFS weights on all usable shipments were then adjusted to account for nonresponse in each stage of sampling. For shipment nonresponse and quarter nonresponse, the approach was simple. In each case, we adjusted the weights by the ratio of the total number sampled (shipments sampled or 4 quarters) to the number for which we received usable data. To account for establishment nonresponse (establishments that provided no usable data for the entire survey), we applied the SIC-level Census-adjustment factor to the CFS weights on shipments from responding establishments. (This procedure is discussed in Sections 4 and 5.)

Finally, estimates were produced for the variables number of shipments, value, shipment weight, ton-miles, and several others. Let y_{hiqj} be the value of a characteristic as reported on shipment j in quarter q from establishment i in stratum h. Similarly, let w_{hiqj} be the CFS weight associated with the shipment, as described above. (This weight includes factors for the Census adjustments to be described in the next section.) Then the CFS estimator of total for this characteristic has the general form

$$\Sigma_h \Sigma_i \Sigma_q \Sigma_j w_{hiqj} y_{hiqj}$$

where the sums are over all shipments, quarters, establishments, and strata.

4. REASONS FOR ADJUSTING THE CFS TO THE CENSUS

We performed a census adjustment in an effort to correct for the errors introduced into our CFS estimates by the three stages of sampling and from other sources. Although the Economic Census is susceptible to non-sampling errors, it is presumed to be more reliable than any survey since it represents a complete enumeration of the population of interest. Comparing CFS estimates of value of shipments to the corresponding Census totals gave us an indication of how much error was present in the CFS estimates and allowed us to adjust the estimates to appropriate levels.

Using value of shipments as the linking variable, we performed two separate adjustment procedures, both of which used results from various components of the 1992 Economic Census. The first procedure adjusted establishment-level estimates of value of shipments from CFS to the corresponding Census totals for the same

establishments. The second procedure adjusted estimates at the 3-digit SIC level. We used 3-digit SICs because that is the level of detail at which the sample was selected.

The purpose of the establishment-level Census adjustment was to correct for various types of error in establishment-level estimates. One source of error is sampling variance, which could have arisen from either of the two stages of within-establishment sampling: the selection of the two-week reporting periods or the sampling of shipments within the reporting period. Estimates from establishments with highly variable shipping patterns, either within a typical two-week period or from one part of the year to another, will tend to have high sampling variances due to either or both stages of sampling. This variance could cause the CFS estimate for an establishment to differ substantially from the corresponding Census value of shipments.

In addition to sampling variance, there is also the potential for sampling bias in the establishment estimates. Some respondents may have misunderstood the instructions for selecting a sample of their shipments. For instance, our evidence indicates that some respondents did not select a systematic sample but instead simply reported the first 50 shipments in their file for the two-week period, filling up all 50 lines on the report form. Incorrect sampling could result in sampled shipments not being representative of the establishment's activity, which could in turn introduce bias into the estimates.

The establishment-level adjustment also corrects for nonsampling errors in the reporting of the establishment's shipments. One major source of nonsampling error is incorrect reporting of the total number of shipments for the two-week period. To properly weight the sampled shipments, we need to know how many total shipments the sample is representing. If this number was reported incorrectly, which our evidence indicates happened frequently, our resulting shipment weight would be inaccurate, producing an inaccurate estimate for the establishment.

The SIC-level estimates from CFS, like the establishment estimates, are subject to sampling variability, which is introduced by the sampling of establishments within each SIC. Census-adjusting the CFS SIC-level estimates makes sure that the estimates are at their proper levels. However, the SIC-level Census adjustment serves additional functions that are more important than correcting for sampling error.

First, the SIC-level adjustment accounts for nonresponding establishments. By computing the Census-adjustment factor for an SIC and applying it to all establishments in that SIC, we allow the responding establishments to represent the nonrespondents. Since the SIC-level adjustment implicitly accounts for only those nonrespondents that were inscope to the survey (i.e., those that were actually shippers), we didn't need to worry about determining whether individual nonrespondents would have been inscope if we had been able to contact them.

Second, the SIC-level adjustment accounts for establishments that were inscope to CFS but were not subjected to sampling. The sample was selected from a frame consisting of establishments that were in business at any time during 1991, but the survey was not conducted until 1993. We had no mechanism in place to capture birth establishments, i.e., new establishments that commenced operation during 1992 or 1993. Also, some inscope establishments were incorrectly classified as out-of-scope because of inaccurate SIC codes at the time of sampling and thus had no chance of ever being added to the sample. Adjusting the CFS SIC-level estimates to their corresponding Census totals --- projected to 1993 levels --- eliminates these problems by allowing respondent establishments to represent births and misclassified establishments in the same way that they represent nonrespondents.

Our decision to perform these two Census-adjustment procedures presented us with several obstacles, not the least of which was that the CFS and the Economic Census were not collected in the same year; to perform the adjustments, we needed to estimate what a hypothetical 1993 Census would have given us. However, we felt that the benefits were great enough to justify the additional time and complexity of finding solutions to the problems.

5. CENSUS-ADJUSTMENT PROCEDURES

5.1 Conversion of Census Totals from 1992 to 1993

After identifying the nearest equivalent to value of shipments in each trade area, we retrieved Census value of shipments $Y_{h,i}^{CENSUS}$ for each establishment that had a matching record on one of the Census databases. We also retrieved Census totals at the 3-digit SIC level, denoted Y_{SIC}^{CENSUS}.

Before computing any adjustment ratios, we inflated (or deflated) the 1992 Census totals to 1993 levels. We produced a 1992-to-1993 inflation factor for each 3-digit SIC, using results from the 1992 and 1993 editions of the appropriate annual surveys --- the Annual Survey of Manufactures, Annual Trade Survey (measuring wholesale trade), Annual Retail Trade Survey, and Service Annual Survey. (We were unable to produce inflation factors for mining SICs, since there

is no annual survey in mining and we were unable to determine another variable, available on a yearly basis, that was sufficiently correlated with value of shipments.) For each SIC, we took the ratio of the 1993 total value of shipments to the 1992 total as our inflation factor and applied this factor to the 1992 Census total for the same SIC.

Ideally we would have liked to inflate each individual establishment's estimate separately, since year-to-year growth rates can vary widely even among establishments in the same industry. However, value of shipments information was not available for all establishments for 1993.

5.2 Computation of Adjustment Ratios

Once we had inflated the Census totals to an approximate 1993 level, we then constructed the CFS estimates to be used in the adjustment procedure. We computed establishment-level estimates of value of shipments for each establishment on the sample file, and we computed estimates of value of shipments for each 3-digit SIC for the aggregate-level adjustment.

For each establishment on the sample file, we computed an estimate $\hat{Y}_{h,i}^{CFS}$ of value of shipments from its CFS data. We then computed the establishment-level Census-adjustment ratio as $Y_{h,i}^{CENSUS}/\hat{Y}_{h,i}^{CFS}$ for any establishment that matched to the Census. For establishments that didn't match to the Census, we set the ratio equal to 1. This adjustment ratio then became a component of the weight w_{hiqj} for each shipment within the establishment.

After Census-adjusting all establishments that matched to the Census in a particular SIC, we added their *adjusted* CFS estimates of value of shipments, multiplied by the corresponding establishment weights, to create an SIC estimate from CFS, $\hat{Y}_{SIC}^{CFS}$. The SIC-level Census-adjustment ratio was then $Y_{SIC}^{CENSUS}/\hat{Y}_{SIC}^{CFS}$, the ratio of the Census total to the CFS estimate of value of shipments for the same SIC. This ratio also became a component of the final CFS weight w_{hiqj} for all shipments from all establishments in the SIC.

Because all estimates produced in CFS are constructed from individual shipment records, and because both Census-adjustment factors were included as components of the weights applied to the shipment records, the adjustment affects estimates of *all* characteristics, not just value of shipments. Thus the Census-adjustment procedures aim to adjust all estimates to appropriate levels while preserving the proportional relationships between variables as given by the survey.

6. RESULTS

6.1 SIC-Level Adjustment Ratios

Upon first inspection, the SIC-level adjustment factors looked reasonable. Most factors were between 1 and 2, which is to be expected, since establishment nonresponse will generally cause CFS estimates to fall short of the Census totals. A few factors were less than 1, but only slightly so, and most of them occurred in SICs with relatively high response rates. In this case the error present in establishments that didn't match to the Census could outweigh the relatively minor shortfall due to nonresponse, with the result that the CFS estimate is actually greater than the Census total for the SIC. Very few factors were larger than 2, and these occurred in SICs with very low response rates.

6.2 Establishment-Level Adjustment Ratios

Our first look at the establishment-level adjustment ratios was not so encouraging. While we had hoped that most of the ratios would be reasonably close to 1, the actual distribution showed marked variability. In a few cases, the CFS overestimated or underestimated the corresponding Census number by a factor of 10,000 or more.

Among those establishments whose ratios were not set to 1, the median of the distribution was 1.04, indicating that there was no systematic tendency for the CFS to either overestimate or underestimate the Census. However, the ratios had a high variability about the median. The first and third quartiles, for instance, were 0.71 and 1.85, respectively; the low and high sixteenths (the 6.25 and 93.75 quantiles, respectively) were 0.31 and 9.92.

This high variability likely stems from the substantial amount of variance and nonsampling error present in the CFS establishment-level estimates, as mentioned in Section 4. No prior attempts were made to correct these errors, so the comparison to the Census in effect served as a way to identify establishments with data problems. We are currently designing edits to correct some of the specific problems that we have discovered through closer examination of establishments with adjustment ratios very far from 1.

Before analyzing the CFS estimates, we excluded from the computations establishments whose adjustment ratios were very far from 1, i.e., establishments having obvious problems with their data. We determined outlier cutoffs based on the distribution of the logs of the ratios, rather than the ratios themselves, since the distribution of the logs should theoretically be roughly symmetric about 0, assuming that the CFS is equally

likely to overestimate or underestimate the Census by the same factor. The distribution was indeed roughly symmetric, although the upper tail (where CFS was much smaller than Census) appeared slightly thicker than the lower tail (where CFS was much larger than Census).

We chose the cutoffs by inspection rather than through any systematic method because we wanted to take into account both the number of establishments that would be excluded and the number of actual shipments. Converted back into the absolute scale, our cutoffs translated into values of 10 and 0.10; any establishment whose adjustment ratio was greater than 10 or less than 0.10 was excluded from further analysis of the estimates.

6.3 Effects of Census Adjustment on CFS Estimates

To assess the effects of the adjustments, we compared estimates of both value and tons at the SIC level, computed under three different adjustment scenarios. The three scenarios compared were:

case 1: no adjustments at all, i.e., let CFS estimates stand on their own

case 2: establishment-level adjustment only

case 3: both establishment-level and SIC-level adjustments

Note that the second scenario is not one we considered using; we computed those estimates to isolate the effects of the two adjustments.

We looked first at estimates of value of shipments at the 3-digit SIC level. Because this is the variable used to compute the adjustment factors, the CFS estimates of value of shipments for the SICs and for most individual establishments are constrained to equal their Census values. Still, looking at estimates of value of shipments serves several purposes. Comparing case 1 to case 2 gives an idea of the amount of error present in the CFS establishment-level estimates, error that the Census adjustment is meant to correct. Comparing case 2 to case 3 indicates roughly how much of the total value of shipments for the SIC was attributable to the portion of the universe represented by nonrespondents, births, and misclassified establishments.

In almost all SICs, the estimate of value of shipments was smaller in case 2 than in case 1. This is not surprising, recalling that the distribution of the logs of the adjustment ratios was roughly symmetric about 0. This means, for instance, that for every establishment that *overestimates* the Census by a factor of 5 (hence having an adjustment factor of 0.2), we can expect another establishment to *underestimate* the Census by a factor of 5 (hence having an adjustment factor of 5). In absolute terms, however, the amount *added* to the total by adjusting the underestimates upward won't make up for the amount *subtracted* by adjusting the overestimates downward when comparing the sum of the unadjusted establishment estimates (case 1) to the sum of the adjusted estimates (case 2).

The drop in the total from case 1 to case 2 was typically around 10-30%, with very few SICs having a drop of 50% or more. No SICs were obvious outliers. The consistency of the magnitude of the adjustment across SICs suggested that the establishment-level Census adjustment was indeed correcting for sampling and nonsampling error in the within-establishment sampling and reporting.

The estimates of value of shipments in case 3 were typically between 1 and 2 times as large as the case 2 estimates. (As mentioned in Section 6.1, most of the adjustment factors were between 1 and 2.) We expect that the differences are due mostly to establishment nonresponse and undercoverage, which the SIC-level adjustment is meant to correct. In the few SICs in which case 2 estimates were greater than case 3, the problem may be caused by unmatched (and hence unadjusted) establishments having errors that result in their CFS weights (and hence their estimates) being unduly large. We are currently designing edits to correct this type of problem.

We also looked at estimates of tons at the 3-digit SIC level. While the effect of the adjustments on estimates of value of shipments looked reasonable, we wanted to make sure that the adjustments were not adversely affecting estimates of other characteristics. Because the relationship between value and tons varies from one establishment to another within an SIC, and because each individual establishment is Census-adjusted by a different ratio, the effect on the estimate of tons for an SIC could be very different from the effect on value. That is, by adjusting individual establishments separately, we fail to preserve the relationship between value and tons at any aggregate level.

We found the effects on tons to be similar to the effects on value at the 3-digit SIC level. As expected, the proportional relationships between the cases were different from the corresponding relationships for value because of the differing value-to-weight relationships among establishments in the same SIC. On the whole, however, there were no drastic differences between the adjustment's effects on tons compared to its effects on

value.

Finally, we looked at estimates of both value and tons by *mode of transport*. We wanted to observe the effects of the adjustment on estimates for a level of aggregation different from that at which the Census adjustment was performed. The shipments used in constructing an estimate for a particular mode can originate from establishments in any number of SICs, so shipments contributing to the same estimate can have different values of the SIC-level adjustment factor as well as different values of the establishment-level factor. Also, mode estimates are not constrained to equal totals from any source external to the CFS, so their behavior under the adjustments is less predictable than that of the SIC estimates. In spite of these differences, the pattern for estimates by mode was roughly the same as for estimates by SIC. Thus the effect of the adjustment appears not to depend on whether a particular estimate is constructed from shipments that originate exclusively from establishments in the same SIC.

7. SUMMARY

Our comparison of the estimates under the three scenarios described in Section 6.3 seems to indicate that the adjustment is accomplishing its goals: correcting for sampling and nonsampling errors at all three stages of sampling, and accounting for establishment nonresponse and coverage deficiencies. The effects of the adjustments are consistent across SICs, among different characteristics, and among estimates computed at different levels of aggregation, which suggests that the adjustments are not having any unexpected, adverse effects on any of the estimates. Thus it appears that the Census adjustment has improved the quality of all our estimates, not just estimates of value of shipments.

In addition, the establishment-level adjustment has drawn our attention to establishments that have problems with their data --- problems that should be corrected. By concentrating our analysis on establishments whose adjustment ratios fell beyond our cutoffs, we have identified several types of nonsampling errors that have potentially harmful effects on the estimates. By specifying edits to correct these errors, we will improve the quality of our estimates still further.

Finally, our experience with the Census-adjustment procedures has suggested several improvements that we could incorporate into future installments of the CFS. In some SICs the Census adjustments had a more pronounced effect on the estimates than in most. This more significant disagreement between CFS and Census may be evidence of consistent reporting problems in these SICs that we could alleviate by introducing new variations of the questionnaire tailored to particular industries.

For the 1997 CFS, we will consider other more direct methods to treat establishment nonresponse. We will also consider other procedures for estimating the contributions of birth establishments and misclassified establishments. While the SIC-level Census adjustment proved an effective way to ensure that CFS estimates reflected universe levels, the estimates may benefit from a more sophisticated treatment of the nonresponse and undercoverage issues, one that doesn't implicitly assume that the characteristics of nonrespondents and births are similar to those of the respondents.

Most importantly, in future versions of the CFS, we will implement all data edits and consistency checks *before* performing the Census adjustment. Some of the edits that we have formulated based on the results of the Census adjustment will, presumably, greatly improve the quality of the CFS estimates. If these are included in the editing and weighting procedures in future versions of the CFS, the resulting CFS estimates should be much closer to standing on their own.

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