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Procedures to Adjust for Nonresponse to the June Enumerative Survey

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ABSTRACT

The purpose of this project was to evaluate procedures which adjust for entire farm nonresponse to the June Enumerative Survey. Three automated procedures were compared to the operational procedure which requires the field staff to impute data for all nonrespondents. Using six states, an analysis compared entire farm and weighted estimates of eight hog and cattle variables for both the entire area frame (excluding extreme operators) and the nonoverlap domain. One of the automated procedures required a classification during data collection as to whether nonrespondents had positive, zero, or unknown numbers of hogs and cattle, and this procedure gave the most accurate estimates. A forthcoming study will analyze effects of these procedures on the December Enumerative Survey before a final recommendation on whether SRS should adopt the automated procedure.

CONTENTS:

SUMMARY

The current operational procedure on the June Enumerative Survey (JES) requires that during data collection the field staff impute both tract and entire farm data for all nonrespondents. Some indication of tract data for nonrespondents can usually be observed by the enumerator, but entire farm data is often more difficult to assess. The purpose of this study was to evaluate three alternative procedures which adjust entire farm and weighted estimates of hogs and cattle without imputing entire farm data for the nonrespondents. This study used data from the 1983 JES for four hog and four cattle variables in six states--Georgia, Illinois, Iowa, Kansas, Ohio, and Wyoming.

The first test procedure assumed that within each paper stratum the nonrespondents were like the respondents. Procedure 2 was similar to procedure 1 except that the assumption applied to the segment level rather than to the paper stratum level. Procedure 3 assumed that within each paper stratum the nonrespondents who had hogs were like the respondents who had hogs. When it was unknown if a group of nonrespondents had hogs, then those nonrespondents were assumed to be like the rest of the sample.

After analyzing entire farm and weighted estimates, the recommendation of this report is to accept procedure 3 as a replacement for the operational procedure. Procedure 3, in distinguishing between positive and zero nonrespondents, was obviously using more realistic assumptions than procedures 1 and 2 and corresponded to the nonresponse procedure being considered for list frame estimates of hogs and cattle. For most variables, procedure 3 gave estimates which were not significantly different from the operational procedure. For most variables where the estimates were different, procedure 3 usually improved over imputation by the field staff. Only for entire farm estimates of milk cows did procedure 3 show a possible bias, and this result may have indicated a need to designate dairy operations.

Procedure 3 represents a logical, automated method of adjusting for entire farm nonresponse. It is a consistent, objective procedure that can be applied from state to state. Because procedure 3 still allows the statistician to impute data when reliable information is available about a farm operation, it represents the best of the current operational method and automated adjustments.

PROCEDURES TO ADJUST FOR NONRESPONSE TO THE JUNE ENUMERATIVE SURVEY

INTRODUCTION

The Statistical Reporting Service (SRS) conducts surveys to estimate livestock inventories, crop acreages, and other agricultural items. The principal SRS survey is the June Enumerative Survey (JES), which uses a nationwide area sample to provide data for these agricultural estimates. The JES uses tract and entire farm estimators in all states and a weighted estimator in 10 states to provide estimates of livestock data. One problem of the JES is nonresponse. When farmers refuse to provide survey information for the JES or are inaccessible, the field staff must impute data for these nonrespondents. Enumerators generally provide notes on the livestock they have observed inside the segment on the operations of nonrespondents. Thus, tract data for nonrespondents can usually be observed, but it is more difficult and often impossible for the field staff to assess entire farm data for nonrespondents.

In order to impute entire farm data for nonrespondents, survey statisticians use whatever observations the enumerator may have been able to make. For operators residing in the segments, observed data can be helpful although perhaps not definite. Other information on nonrespondents can be obtained from: 1) Agricultural Stabilization and Conservation Service, particularly for larger farms, 2) questionnaires from previous years, and 3) control data on the list frame if the nonrespondent is on the list. The nonrespondents that are the most difficult to impute for are refusals in new segments, operators who are nonoverlap with the list, and operators who have livestock located outside the segment.

Statisticians usually find imputation easier for livestock inventory than for births, deaths, purchases, or future intentions. The latter items can really only be estimated for nonrespondents through relationships that hold for respondents. Thus, automated nonresponse procedures that use this concept seem more reasonable for these types of items than the operational procedure.

This report summarizes the results of a study conducted during the 1983 JES that examined three automated procedures which adjusted entire farm and weighted estimates for nonresponse. This report begins by summarizing past SRS research that studied nonresponse adjustments and then describes the estimators and procedures used in this study. Next, the estimates from the operational procedure are compared with those from the three alternative procedures for eight livestock variables. Finally, the report discusses the results of these comparisons and makes recommendations.

BACKGROUND

SRS has done a considerable amount of research on the problem of nonresponse in list frame surveys to estimate hogs and cattle. In 1973 the Statistical Laboratory at Iowa State University, under a cooperative agreement with SRS, interviewed 196 farmers who were cooperators with SRS surveys and 190 noncooperators (8). Analysis showed that there were no significant differences in the average age, number of years in farming, and educational attainment of the two groups, but that noncooperators tended to have larger farm operations than cooperators. For example, average acreage operated, number of hogs marketed, and gross farm sales were all significantly larger for noncooperators than cooperators.

In 1976 Ford (3) did a simulation study to examine six procedures which made automated adjustments for nonresponse on list frame surveys. The six procedures included ratio, regression, and hot deck procedures. The study found no significant differences in estimated means from the six procedures. In 1978 Ford (4) continued his simulation study in a more sophisticated experiment. The major finding of this research was that no automated procedure could improve upon the operational procedure for list frame surveys unless the control data has a correlation larger than 0.60 with survey variables or unless additional information is obtained on the nonrespondents. In an overview of the problem, Ford recommended that SRS either improve the quality of control data or obtain additional information on the nonrespondents.

In 1978 Crank (2) examined the idea of obtaining additional information on nonrespondents. This research was also motivated by the likelihood that the proportion of nonrespondents with livestock was higher than the proportion of respondents with livestock. Research was done on list surveys of hogs and cattle in Illinois, Iowa, and Nebraska. Each nonrespondent was coded to indicate: 1) had hogs, 2) had no hogs, or 3) unknown whether had hogs. A similar coding scheme was used for cattle. Using procedures which accounted for this additional information on the nonrespondent, the livestock estimates were found to be 2 to 6 percent higher than the operational estimates. Currently, for multiple frame surveys of hogs and cattle, SRS codes all nonrespondents in the list sample to indicate zero, positive, or unknown number of livestock.

SRS has done a small amount of research on nonresponse in area frame surveys. A 1976 study (1) in Oklahoma examined the effect of nonresponse on the cattle estimates from the December Enumerative Survey. In that study about 5 percent of the tract and weighted estimates resulted from imputing data for nonrespondents. In particular, steers and heifers which weighed 500 pounds or more and which were not for replacement appeared to be underimputed by the statisticians.

In 1978 Ford (5) compared two adjustment procedures with the operational procedure of editing in data for nonrespondents on area frame surveys. One procedure was to delete all nonrespondents from summarization and increase the expansion factors of the respondents. The other adjustment was to regress entire farm data on observed tract data. Using data from the 1976 JES in Iowa, analysis found no significant differences in hog and cattle estimates from the two test procedures and the operational procedure. However, the analysis was not powerful because the testing was only done in one state.

DESIGN OF THE STUDY

The purpose of this study was to compare the operational method of adjusting for entire farm nonresponse with three alternative procedures. These three procedures were automated, objective methods which could be applied consistently across all states. This property contrasted with the subjective nature of the operational procedure. The estimates from the operational procedure were not considered the "best estimates" in this study but were used to gauge the effects of the alternative procedures. Formulas for the procedures are described in Appendix A.

Procedure 1 ignored the data imputed for all nonrespondents and increased the expansion factors for the respondents by the ratio of the number of all operators in the paper stratum to the number of respondents in the paper stratum. If a paper stratum was composed completely of nonrespondents, then procedure 1 made a similar adjustment at the level of the landuse stratum--a situation that rarely occurred. This procedure was similar to one used in Ford's 1978 study (5). Procedure 1 assumed that within a paper stratum the data for nonrespondents were distributed the same as the data for respondents.

Procedure 2 was like procedure 1 except that the adjustment for nonrespondents was made at the segment level rather than at the paper stratum level. If all the operators in a segment were nonrespondents, then an adjustment was made at the paper stratum level like procedure 1. Procedure 2 assumed that within a segment the data of nonrespondents were distributed the same as the data of respondents.

Procedure 3 took advantage of a classification of all nonrespondents as either: 1) "positive hogs" — had a positive number of hogs, 2) "zero hogs" — had no hogs, or 3) "unknown hogs" --unknown whether had hogs. A similar classification was done for cattle. The adjustment of procedure 3 was then similar to procedure 1 except that procedure 3 ignored the data imputed for "positive" nonrespondents and increased the expansion factors of "positive" respondents by the ratio of the number of all "positive" operators to the proportion of "positive" respondents. (It was assumed that the number of "unknowns" having hogs or cattle was the same as the rest of the sample.) Thus, procedure 3 assumed that "positive" nonrespondents were distributed the same as "positive" respondents. Procedure 3 corresponded to nonresponse procedures suggested by Crank (2) for list frame estimates of hogs and cattle.

Data was analyzed from the 1983 JES in six states: Georgia, Illinois, Iowa, Kansas, Ohio, and Wyoming. SRS selected these states because of their geographic diversity, varying nonresponse rates, and large livestock inventories. Because using all livestock variables would have resulted in a very complicated analysis, eight representative variables were analyzed: 1) total hogs and pigs; 2) sows, gilts, and young gilts; 3) expected farrowings of sows and gilts in the next quarter; 4) hogs purchased since December 1, 1982 that were still on hand; 5) total cattle and calves; 6) milk cows; 7) steers and heifers which weighed 500 pounds or more and were not for replacement; and 8) calves born since January 1, 1983.

Hog estimates were not analyzed in Wyoming because of the small number of hog operations. Also, Wyoming did not collect data for weighted estimates. Thus, in the following text references to "six states" will actually only include five states for hog estimates and all weighted estimates. Also the reader should note that all extreme operators for hogs and cattle were excluded from the analysis. Formulas for both the entire farm and weighted estimators of the operational program are described in Appendix B.

NATURE OF THE NONRESPONDENTS

Before comparing the estimates from the different procedures, it is important to describe the nature of the nonrespondents in the collected data. Table 1 shows the nonresponse rates for hog and cattle data in each of the six states in the study. These rates were calculated by dividing the number of agricultural tracts of a certain type (e.g. refusal tracts) by the total number of agricultural tracts. Kansas had the highest nonresponse rate while both Ohio and Georgia had low nonresponse rates.

Table 1: Nonresponses rates for six states during the 1983 June Enumerative Survey.

STATE	HOGS		CATTLE	
	Refusal	Inaccessible	Refusal	Inaccessible
Georgia	6.1	0.0	4.0	2.5
Illinois	9.3	0.7	8.7	1.2
Iowa	9.6	1.0	8.1	0.9
Kansas	12.6	3.4	10.0	3.0
Ohio	3.6	0.8	5.5	1.3
Wyoming	7.7	0.0	9.6	2.9
Six States	**8.6**	**1.0**	**7.8**	**1.9**

Table 2 shows the number of nonrespondents coded positive, zero, and unknown. For hogs, about half the nonrespondents across the six states were unknowns. In Iowa most of the nonrespondents were known to be positive or zero while in Georgia and Ohio most of the nonrespondents were unknowns. For cattle, the percentage of unknowns was slightly less --about 40%. This result was caused by the fact that most of the nonrespondents were known to be positive or zero in Iowa, Kansas, and Wyoming. The reader should note that in each state there were always more positive than zero nonrespondents for cattle, but that the same relationship was not always true for hogs.

Table 2: Number of nonrespondents: 1) known to have a positive number of livestock, 2) known to have zero livestock, and 3) unknown whether had livestock for the 1983 June Enumerative survey in six states.

STATE	HOGS			CATTLE		
	Positive	Zero	Unknown	Positive	Zero	Unknown
Georgia	16	5	58	37	1	41
Illinois	39	23	64	49	15	56
Iowa	85	26	28	83	16	33
Kansas	26	76	109	101	22	84
Ohio	7	17	44	21	7	32
Wyoming 1/	-	-	-	14	2	4
Six States	**173**	**147**	**303**	**305**	**63**	**250**

1/ In this study hog estimates were not analyzed in Wyoming because of the small number of hog opertions. For cattle, the Wyoming data is from resident farm operators only.

Table 3 illustrates the difference between respondents and known nonrespondents in terms of the percentage having livestock. For both hogs and cattle, this percentage was much larger for known nonrespondents. This result is evidence against the validity of the assumptions for procedures 1 and 2.

Table 3: Percentage of respondents and known nonrespondents having livestock during the 1983 June Enumerative survey.

STATE	HOGS		CATTLE	
	Respondents	Known Nonrespondents	Respondents	Known Nonrespondents
Georgia	22.6	76.2	59.3	97.4
Illinois	26.2	62.9	44.7	76.6
Iowa	45.1	76.6	57.2	83.8
Kansas	12.5	25.5	68.7	82.1
Ohio	21.2	29.2	52.1	75.0
Wyoming 1/	--	--	71.2	87.5
Six States	25.9	54.1	56.3	82.9

1/ In this study hog estimates were not analyzed in Wyoming because of the small number of hog operations. For cattle, the Wyoming data is from resident farm operators only.

In the remaining analysis of this study, nonrespondents will only refer to nonrespondents for whom there was no reliable information. This slight modification arose because all the alternative procedures used the imputed data as reported data when there was reliable information on a nonrespondent.

COMPARISONS OF PROCEDURES--ENTIRE FARM ESTIMATES

For six-state totals of hogs and cattle, Table 4 displays relative differences among the entire farm estimates and Table 5 displays the coefficients of variation (CV's). The estimates showed little difference although procedure 3 showed a tendency to be slightly higher than the other procedures. The CV's from the alternative procedures although approximations (see Appendix A), were always larger than the operational procedure. The increase did not indicate that the alternative procedures were less precise than the operational procedure, but that the CV's of the alternative procedures better reflected the imprecision in the data due to nonresponse. The operational procedure ignored the imprecision due to nonresponse by summarizing the data imputed for nonrespondents as though that data were reported. Thus, Table 5 reveals a small downward bias in the operational CV's.

Table 4: For entire farm estimates across six states during the 1983 June Enumerative Survey, relative differences between the operational procedure and procedures 1-3 as percentages of the operational estimates. Positive percentages indicate estimates which were larger than the operational estimates and negative percentages indicate smaller.

HOGS

	Total Hogs	Sows	Hogs Purchased	Expected Farrowings
Procedure 1	-2.2%	-2.2%	2.0%	-3.0%
Procedure 2	-2.2%	-2.3%	0.8%	-4.1%
Procedure 3	1.1%	1.2%	7.1%	0.5%

CATTLE

	Total Cattle	Milk Cows	Steers and Heifers	Calves Born
Procedure 1	3.0%	-5.5%	0.9%	-0.3%
Procedure 2	2.6%	-7.5%	1.2%	1.6%
Procedure 3	1.8%	-5.5%	3.2%	0.8%

Table 5: For entire farm estimates, coefficients of variation for six-state totals from the 1983 June Enumerative Survey.

HOGS

	Total Hogs	Sows	Hogs Purchased	Expected Farrowings
Operational	**7.2**	**7.2**	**13.9**	**7.9**
Procedure 1	7.5	7.5	14.6	8.6
Procedure 2	7.5	7.5	14.9	8.5
Procedure 3	7.5	7.8	14.8	9.0

CATTLE

	Total Cattle	Milk Cows	Steers and Heifers	Calves Born
Operational	**5.6**	**10.3**	**10.0**	**6.6**
Procedure 1	6.0	10.9	10.3	7.1
Procedure 2	7.1	10.8	10.5	8.0
Procedure 3	6.0	10.8	10.4	7.1

Entire farm estimates and CV's for individual states are in Appendix C.

Multivariate paired t-tests were run to make overall comparisons of the procedures. Because there were no conventional multiple comparison tests for multivariate data, multivariate tests were run on the procedures two at a time in order to locate which procedures were significantly different from each other. Formulas for univariate and multivariate t-tests are described in Appendix F.

The significance levels from the multivariate tests are in Table 6. These tests showed that:

1) The alternative procedures were not significantly different from the operational procedure at the 10% level. However, procedure 2 was almost significantly different from the operational procedure for the cattle variables. Univariate paired t-tests (see Appendix C) indicated that the major reason for this difference was an underestimation of milk cows by procedure 2 --an underestimation that Table 4 showed

occurring for all the alternative procedures. This underestimation resulted from statisticians imputing data in several states so that the average number of milk cows was much higher for nonrespondents than for respondents. In Illinois the average was 5.6 for nonrespondents vs. 2.7 for respondents, in Kansas 3.4 vs. 1.6, and in Ohio 8.2 vs. 3.5. The same relationships also tended to be true for positive operators. Thus, either the imputations were too high or, more likely--the alternative procedures underestimated because they assumed that respondents were like nonrespondents. Perhaps a code was needed to designate dairy operations which have a large number of milk cows.

2) Usually the estimates from procedure 3 were significantly different from procedures 1 and 2. This result was expected because procedure 3 would give slightly higher estimates than estimates from procedures 1 and 2 when the nonrespondents had a higher percentage of positive operators than the respondents.

Table 6: Significance levels of multivariate paired t-tests to determine if the entire farm estimates from each pair of procedures are the same. Data for tests were six-state totals from the 1983 June Enumerative Survey.

Test	Hogs	Cattle
Operational vs. Procedure 1	0.46	0.43
Operational vs. Procedure 2	0.25	0.11
Operational vs. Procedure 3	0.36	0.18
Procedure 1 vs. Procedure 2	0.16	0.31
Procedure 1 vs. Procedure 3	0.02	0.01
Procedure 2 vs. Procedure 3	0.07	0.13

In general, univariate tests comparing each of the alternative procedures to the operational procedure showed the same results as the multivariate tests. The univariate results are described in Appendix C along with tests for individual states.

COMPARISONS OF PROCEDURES--WEIGHTED ESTIMATES

For six-state totals of hogs and cattle, Table 7 displays weighted estimates and Table 8 displays CV's. As for entire farm estimates, the CV's were all slightly higher for the three alternative procedures than for the operational procedure. This result again represented a small downward bias in the operational CV's.

Table 7: For weighted estimates of six-state totals from the 1983 June Enumerative Survey, relative differences between the operational procedure and procedures 1-3 as percentages of the operational estimates. Positive percentages indicate estimates which were larger than the operational estimates and negative percentages indicate smaller.

HOGS

	Total Hogs	Sows	Hogs Purchased	Expected Farrowings
Procedure 1	-3.2%	-3.4%	5.3%	-3.2%
Procedure 2	-2.9%	- 3.6%	6.0%	-3.7%
Procedure 3	1.1%	0.9%	10.5%	0.8%

CATTLE

	Total Cattle	Milk Cows	Steers and Heifers	Calves Born
Procedure 1	-0.1%	-0.8%	0.4%	-0.9%
Procedure 2	-0.1%	-1.5%	0.1%	-0.9%
Procedure 3	1.8%	0.2%	3.0%	0.9%

Table 8: For weighted estimates, coefficients of variation for six-state totals from the 1983 June Enumerative Survey.

HOGS

	Total Hogs	Sows	Hogs Purchased	Expected Farrowings
Operational	**4.5**	**4.9**	**9.5**	**5.2**
Procedure 1	4.7	5.3	10.0	5.7
Porcedure 2	4.7	5.2	10.3	5.6
Procedure 3	4.7	5.3	10.2	5.7

CATTLE

	Total Cattle	Milk Cows	Steers and Heifers	Calves Born
Operational	**2.6**	**9.7**	**5.8**	**2.9**
Procedure 1	2.8	10.6	6.2	3.1
Procedure 2	2.7	9.8	5.9	3.0
Procedure 3	2.8	10.6	6.2	3.1

Table 9 shows the results of multivariate paired t-tests on the weighted estimates. The results for weighted cattle variables, which were similar to those for entire farm estimates of cattle, showed that:

1) The three alternative procedures were not significantly different from the operational procedure. However, the underestimation of milk cows which occurred for entire farm estimates did not occur for weighted estimates.

2) Procedure 3 was significantly different from procedures 1 and 2 and gave slightly higher estimates than those procedures.

Table 9: Significance levels of multivariate paired t-tests to determine if the weighted estimates from each pair of procedures is the same. Data for tests were six-state totals from the 1983 June Enumerative Survey.

Test	Hogs	Cattle
Operational vs. Procedure 1	0.01	0.63
Operational vs. Procedure 2	0.01	0.51
Operational vs. Procedure 3	0.01	0.98
Procedure 1 vs. Procedure 2	0.53	0.98
Procedure 1 vs. Procedure 3	0.01	0.01
Procedure 2 vs. Procedure 3	0.01	0.02

The weighted hog estimates showed significant differences between each of the alternative procedures and the operational procedure. Univariate tests (see Appendix D) indicated that procedures 1 and 2 were significantly different at the 10% level from the operational procedure for all four hog variables. As Table 7 shows, for three of these variables -- total hogs, sows, and expected farrowings -- procedures 1 and 2 were below the operational estimate.

Table 10: Means for reported vs. imputed data for weighted estimates from the 1983 June Enumerative Survey. Wyoming is not included because its hog estimates were not used in the analysis.

State	Type of Mean	Total Hogs	Sows	Hogs Purchased	Expected Farrowings
Georgia	Reported	13.4	1.9	1.7	0.9
	Imputed	21.1	3.6	1.9	1.9
Illinois	Reported	48.4	5.7	6.4	2.7
	Imputed	114.3	14.2	5.3	7.0
Iowa	Reported	119.2	14.5	19.6	7.1
	Imputed	176.4	22.3	4.5	9.8
Kansas	Reported	13.2	1.7	4.1	0.9
	Imputed	12.1	1.8	2.5	0.8
Ohio	Reported	12.9	1.8	2.0	0.9
	Imputed	28.0	2.4	8.9	1.1

In Table 10 one can see that the low estimates from procedures 1 and 2 arose because of a failure of the assumption that the respondents were like the nonrespondents. The imputed means for total hogs, sows, and expected farrowings were much higher than the reported means -- indicating that the statisticians treated the nonrespondents as having more hogs than the respondents. This treatment is consistent with results from other reports (8) that nonrespondents have larger farming operations than respondents. Thus, procedures 1 and 2 failed to be adequate in this situation because their assumptions were not realistic enough.

In Table 10 the fourth variable -- hogs purchased -- showed the reverse relationship: the reported means were higher than the imputed means (with the exceptions of Georgia and Ohio). Table 11 shows that the same relationship about hogs purchased was also true for positive operations, especially in the important hog states of Iowa and Illinois. For example, in Iowa the average value imputed for positive nonrespondents was 6.5 hogs purchased vs. 49.1 hogs purchased for positive respondents. Thus, the imputed values were probably too low on the average because the number of hogs purchased was a difficult value to impute for nonrespondents even if the nonrespondent's entire farm could be observed by the enumerator. The alternative procedures represented a clear improvement over the operational procedure for this variable.

Tabel 11: For operations with a positive number of hogs, means for reported vs. imputed data for weighted estimates from the 1983 June Enumerative Survey. Wyoming is not included because its hog estimates were not included in the analysis.

State	Type of Mean	Total Hogs	Sows	Hogs Purchased	Expected Farrowings
Georgia	Reported	68.9	9.8	8.6	4.6
	Imputed	108.0	18.6	9.9	9.6
Illinois	Reported	227.9	26.7	30.2	12.7
	Imputed	277.8	34.6	12.8	17.0
Iowa	Reported	297.6	36.3	49.1	17.7
	Imputed	254.9	32.2	6.5	14.2
Kansas	Reported	124.1	16.1	38.6	8.3
	Imputed	119.7	18.2	25.0	8.2
Ohio	Reported	87.2	12.2	13.7	5.7
	Imputed	272.8	23.1	86.6	10.7

In some states steers and heifers had the same problems as hogs purchased. However, steers and heifers did not produce significant differences across all six states because Iowa edited in larger means for the nonrespondents and this offset the effects in other states.

For six-state totals, hogs purchased was the only hog variable for which procedure 3 differed significantly from the operational procedure. Because procedure 3 did not have the problems which procedures 1 and 2 had with the other hog variables, procedure 3 emerged as a better procedure. This result was consistent with the more realistic assumptions of procedure 3.

There were some scattered differences among the procedures for both entire farm and weighted livestock estimates at the state level. In general, there were two causes of these differences. The first was that an occassionally large discrepancy in imputed vs. reported means resulted, as above, in a significant difference among the procedures. The second cause was the effect of "unknown" operations on the procedures. "Unknowns" were nonrespondents for whom it was not known whether they had livestock. The operational procedure estimated the percent of positive unknowns by using percent of the unknowns for whom hogs had been imputed. The alternative procedures estimated the percent of positive unknowns by the percent of positive operators in the rest of the sample.

Table 12 shows the percent of unknowns designated as positive by the alternative procedures vs. the operational procedure. Obviously, the operational procedure treated fewer of the unknowns as positive than the alternative procedures.

Table 12: For nonrespondents classified as "unknowns", percentages of operators eventually determined as having a positive number of hogs or cattle. Wyoming was not included because its hog estimates were not included in the analysis and because it did not collected weighted data for cattle.

STATE	HOGS		CATTLE	
	Operational Procedure	Alternative Procedures	Operational Procedure	Alternative Procedures
Georgia	8.6	23.8	29.3	60.9
Illinois	15.6	27.6	32.1	45.5
Iowa	32.1	47.4	24.2	59.0
Kansas	4.6	13.4	22.6	69.8
Ohio	4.5	21.3	9.4	52.7

It is impossible to tell which procedure was more correct regarding unknowns without knowing the truth about the unknowns. Statisticians appeared to be conservative in imputing for the unknowns -- only imputing positive data when there was some evidence, such as farm equipment, indicating the presence of livestock. The alternative procedures took the natural strategy of treating what was unknown like what was known -- an assumption, however, that may not have been true in this situation.

The effect of the unknowns on the procedures can be minimized in the future by stressing that "unknown" designates those nonrespondents for whom there is reasonable ignorance of whether livestock are present. Under this condition, then the data imputed by statisticians for the unknowns are by definition "wild guesses", and the assumptions of the alternative procedures are clearly more reasonable. The effect of unknowns could be removed altogether by simply taking away the category of "unknown" during coding and forcing all nonrespondents to be coded positive or zero. However, this would probably result in most of the unknowns being coded as "zeros" -- probably an undesirable result.

COMPARISONS OF PROCEDURES--NONOVERLAP DOMAIN

Estimates, CV's and results of univariate tests on the weighted nonoverlap (NOL) can be found in Appendix E. Table 13 gives the results of multivariate tests on both entire farm and weighted estimates for the NOL domain. There were no significant differences between the entire farm estimates because of the small number of resident operators in the NOL domain. For weighted NOL estimates, the hog variables showed a result similar to prior analysis in this study--there were no significant differences between the operational procedure and the alternative procedures, but there was a significant difference between procedure 3 and procedures 1 and 2.

For weighted NOL estimates of cattle, Table 13 shows that there were significant or almost significant differences among all of the procedures. Univariate tests revealed that this significance was mainly a result of the operational estimates being lower than the alternative estimates for steers and heifers. As reported in Tables 10 and 11 for hogs purchased, the reported means for steers and heifers were much larger than the imputed means in Kansas, Ohio, and Georgia. For example, in Kansas the reported mean was 12.5 vs. the imputed mean of 2.8. Thus, this situation seemed to be another case of not imputing enough data.

Table 13: For the nonoverlap domain, significance levels of multivariate paired t-tests to determine if the entire farm and weighted estimates from each pair of procedures are the same. Data for tests were six-state totals from the 1983 June Enumerative Survey.

Test	Entire Farm		Weighted	
	Hogs	Cattle	Hogs	Cattle
Operational vs. Procedure 1	0.80	0.73	0.63	0.11
Operational vs. Procedure 2	0.52	0.75	0.51	0.11
Operational vs. Procedure 3	0.81	0.82	0.98	0.07
Procedure 1 vs. Procedure 2	0.26	0.25	0.98	0.11
Procedure 1 vs. Procedure 3	0.28	0.65	0.01	0.01
Procedure 2 vs. Procedure 3	0.66	0.24	0.02	0.01

CONCLUSIONS

After analyzing entire farm, weighted, and nonoverlap estimates from the JES, this report found that procedure 3 was a reasonable alternative to the operational procedure. In most cases estimates from procedure 3 were not significantly different from the operational procedures, and when there was a significant difference, procedure 3 usually gave more reasonable estimates than the operational procedure. This improvement was particulary true for variables that were difficult or impossible to observe such as hogs purchased. Procedure 3 also gave a better measure of imprecision because its CV's did not have the small downward bias of CV's from the operational procedure. Procedure 3 only seemed to have a problem with entire farm estimates of the number of milk cows. This problem may indicate a need for a code to indicate dairy farms.

As an automated procedure, procedure 3 has several advantages over the operational procedure:

(1) It is an objective method of adjusting for nonresponse as opposed to the subjectivity of the operational procedure. The logic of procedure 3 can be evaluated and its effects measured, as in this study. The operational procedure, however, depends on subjective influences such as the experience, talent, and opinions of personnel. Thus, the effects of the operational procedure vary from state to state and year to year. This subjectivity does not necessarily make the operational procedure an inferior procedure, but it makes measurement of its effects very difficult. Both procedures depend on guesswork -- the operational procedure through the imputing of data for nonrespondents and procedure 3 through the accuracy of its assumption that positive nonrespondents are like positive respondents. However, procedure 3 at least can show how the guesswork was done.

(2) Procedure 3 can be applied consistently from state to state. Thus nonresponse on the JES would have the same effect for all states. Also, procedure 3 is consistent with nonresponse adjustments for list estimates of livestock on multiple frame surveys.

(3) Procedure 3 makes logical and consistent use of additional information (positive, zero, or unknown livestock) which can be obtained with little additional effort during data collection.

(4) Procedure 3 is flexible enough to allow imputation of data when reliable information is known about a nonrespondent. Thus, procedure 3 combines the best aspects of the operational procedure and the automated techniques studied in this report.

A supplement to this report will analyze the effects of procedures to adjust for entire farm nonresponse on the December Enumerative Survey (DES). Although the results in this study are promising, the analysis on the DES is needed in order to make a complete determination. Of course, no automated procedure can replace the efforts of field enumerators in obtaining accurate data. The need for securing the cooperation of farmers needs to be stressed continually no matter what form of nonresponse adjustment is used.

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APPENDIX A

This appendix describes the three alternative procedures used in this report to adjust for hog variables using the farm estimator. The procedures for the cattle variables are similar. The procedures for the weighted estimator are the same as for the farm estimator, except that all agricultural operators are included, rather than just resident agricultural operators (RAO's), and weighted values take the place of farm values. The assumptions are also complicated by the introduction of weighted values. Although analysis took into account problem segments, for the sake of simplicity the following formulas are writen as though there are no problem segments, i.e. all segments in a paper stratum have the same expansion factor.

Notation for a given paper stratum:

n1=number of RAO's in a given paper stratum coded "complete."
n2=number of RAO's coded "nonrespondent with good data."
n3=number of RAO's coded "nonrespondent without good data."
n4=number of RAO's coded "positive."
n5=number of RAO's coded "zero."
n6=number of RAO's coded "unknwn."
n7=number of RAO's coded "unknown" who have positive hogs.

m1=number of RAO's coded "complete" who have positive hogs.
m2=number of RAO's coded "nonrespondent with good data" who have positive hogs.

X1=sum of the entire farm values of the hog variable of interest for all RAO's coded "complete."
X2=sum of the entire farm values of the hog variable of interest for all RAO's coded "nonrespondent with good data."
X3=sum of the entire farm values of the hog variable of interest for all RAO's coded "nonrespondent without good data."
X4=sum of the entire farm values of the hog variable of interest for all RAO's coded "positive."
X7=sum of the entire farm values of the hog variable of interest for all RAO's coded "unknown."

n=n1 + n2 + n3 =number of RAO's in the paper stratum.
X=X1 + X2 + X4 + X7 =sum of the entire farm values for all RAO's in the paper stratum.

Note that n3=n4 + n5 + n6 and X3=X4 + X7.

Procedure 1:

Procedure 1 adjusts for nonresponse at the paper stratum level by inflating the data for all RAO's coded "complete" or "nonrespondent with good data" by the ratio n/(n1 + n2).

If Est.X is the estimated sum of X, then

$$\begin{aligned} Est.X &= X1 + X2 + n3 * (X1 + X2) / (n1 + n2). \\ &= (X1 + X2) * (n/(n1 + n2)) \end{aligned}$$

provided n1 + n2 is not equal to zero. If n1 + n2 =0, then the adjustment is at the level of land use stratum, and similar notation applies.
Procedure 1 assumes that the mean for RAO's coded "complete" or "nonrespondent with good data" is the same as the mean for RAO's coded "nonrespondent without good data." Thus:

$$(X1 + X2) / (n1 + n2) = X3/n3.$$

Procedure 2:

Procedure 2 uses two adjustments, one at the segment level and one at the paper stratum level. Let

s1=number of RAO's in a given segment coded "complete,"
s2=number of RAO's in a given segment coded "nonrespondent with good data, and
s3=number of RAO's in a given segment coded "nonrespondent without good data."
Let

Y1=sum of the entire farm values of the hog variable of interest for all RAO's in the segment coded "complete."
Y2=sum of the entire farm values of the hog variable of interest for all RAO's in the segment coded "nonrespondent with good data," and
Y3=sum of the entire farm values of the hog variable of interest for all RAO's in the segment coded "nonrespondent without good data."

s=s1 + s2 + s3=number of RAO's in the segment and
Y=Y1 + Y2 + Y3=sum of the entire farm values for all RAO's in the segment.

If Est. Y is the estimated sum of the entire farm values for all RAO's in the segment, then

$$\text{Est.}Y = Y1 + Y2 + s3 * (Y1 + Y2) / (s1 + s2)$$

$$= (Y1 + Y2) * s/(s1 + s2), \text{ provided } s1 + s2 \quad 0.$$

This adjustment assumes that the mean for RAO's in a segment coded "complete" or "nonrespondent with good data" is the same as the mean for RAO's in the segment coded "nonrespondent without good data." That is,

$$(Y1 + Y2) / (s1 + s2) = Y3/s3.$$

In case s1 + s2 = 0 for any segment, this adjustment is impossible. Although it is probably better to omit these segments from the data set, in this study an alternative adjustment was used. Suppose u is the total number of RAO's in the paper stratum belonging to segments where s1 + s2 is not equal to zero, and w is the sum of the est. y's over all segments in the paper straatum where s1 + s2 is no equal to zero. Then, the estimated total for the paper stratum is

$$\text{Est.}X = (n/u) * W.$$

This second adjustment assumes that the mean for RAO's in segments where everyone is coded "nonrespondent without gooc data" is the same as the mean for RAO's in all other segments in the paper stratu n..

Procedure 3:

Procedure 3 is like Procedure 1, except that it excludes RAO's with zero hogs from the numerator and denominator of the inflation ratio. For Procedure 3,

$$Est.X = X1 + X2 + n4 * (x1 + X2) / (m1 + m2) + n6 * ((m1 + m2 + n4) / (n1 + n2 + n4 + n5)) * (X1 + X2) / (m1 + m2)$$

$$= (X1 + X2) * (n*(m1 + m2 + n4)) / ((n - n6) * (m1 + m2)).$$

Procedure 3 assumes that the mean for RAO's with hogs coded "complete" or "nonrespondent with good data" is the same as the mean for RAO's with hogs coded "positive." That is,

$$(X1 + X2) / (m1 + m2) = X4/n4.$$

Procedure 3 also assumes that the proportion of RAO's coded "complete," "nonrespondent with good data," "positive," or "zero" who have hogs is the same as the proportion of RAO's coded "unknown" who have hogs. That is,

$$(m1 + m2 + n4) / (n1 + n2 + n4 + n5) = n7/n6.$$

Procedure 3 further assumes that the mean for RAO's with hogs coded "unknown" is the same as the mean for RAO's with hogs coded "complete" or "nonrespondent with good data." That is,

$$(X1 + X2) / (m1 + m2) = X7/n7.$$

All three procedures made some adjustment for nonresponse at the paper stratum level. These adjustments used factors which were based on counts of sample units which fell into different categories, eg. positive respondents, positive nonrespondents. In this study these factors were treated as known population characteristics althrough there was some sampling error associated with them because they were based on sample counts. The sampling error calculations associated with these adjustments would be very complicated, and the current JES summary system may not be able to do them. There should be a small study to evaluate the effects of the true sampling errors.

A previous study (2, pg. 17) tried to take into account the true sampling errors but still had to drop covariances and work with biased estimators. The formulas used in this report for procedures 1-3 should simply be considered approximations which probably tend to underestimate the true sampling error because the variability of certain factors at the paper stratum level have not been taken into account.

APPENDIX B

This appendix describes the estimators used in the data analysis. It also contains the formulas for the estimators and their estimated variances. Each estimator relies on the expansion of a particular value

Entire Farm Value: For each operation, the entire farm value for the variable of interest is 0 if the operator lives outside the segment and is the number of livestock on the entire farm if the operator lives inside the segment. Suppose a farmer had 150 hogs located on his entire farm and he was an RAO. His farm value would be 150. If the farmer was not an RAO, his farm value would be zero.

Weighted Value: For each operation, the weight is the ratio of tract acreage to entire farm acreage. The weighted value is the product of the weight and the number of livestock on the entire farm. Suppose the farmer in the example above had 300 acres on his entire farm, 100 of which were inside the segment. His weight would be 100/300, or 1/3. His weighted value for number of hogs would be 1/3 x 150, or 50.

This appendix presents the formulas for the estimated totals for the farm and weighted estimators discussed earlier. For each estimated total, it also gives the formula for the estimated variance. $\hat{Y}$ represents the estimated total and $\hat{var}(\hat{Y})$ is the estimated variance. These are the same formulas used by Nealon (6).

(1) Entire Farm Estimator:

$$\hat{Y} = \sum_{i=1}^{S} \sum_{j=1}^{P_i} \sum_{k=1}^{r_{ij}} Y'_{ijk} = \sum_{i=1}^{S} \sum_{j=1}^{P_i} \sum_{k=1}^{r_{ij}} e_{ijk} Y_{ijk},$$

where

S = number of land use strata in the state,

P_i = number of paper strata within land use stratum i,

r_{ij} = number of segments within paper stratum j within land use stratum i,

e_{ijk} = expansion factor in paper stratum j within land use stratum i, for segment k.

$$Y_{ijk} = \begin{cases} \sum_{\ell=1}^{g_{ijk}} Y_{ijk\ell} & \text{if } g_{ijk} > 0, \\ 0 & \text{otherwise,} \end{cases}$$

where

g_{ijk} = number of resident agricultural operators (RAO's) within segment k within paper stratum j within land use stratum i,

$Y_{ijk\ell}$ = entire farm value of the variable of interest for tract ℓ within segment k within paper stratum j within land use stratum i, if the operator of tract ℓ is an RAO,
0 otherwise.

$$Y'_{ijk} = e_{ijk} Y_{ijk} \quad .$$

$$\hat{\text{var}}(\hat{Y}) = \sum_{i=1}^{S} \sum_{j=1}^{P_i} \sum_{k=1}^{r_{ij}} \frac{\left(1 - \frac{1}{\bar{e}_{ij.}}\right)}{\left(1 - \frac{1}{r_{ij}}\right)} \left\{ Y'_{ijk} - \bar{Y}'_{ij.} \right\}^2 ,$$

where $\bar{Y}'_{ij.} = \sum_{k=1}^{r_{ij}} Y'_{ijk} / r_{ij}.$

$$\bar{e}_{ij.} = \sum_{k=1}^{r_{ij}} e_{ijk} / r_{ij}.$$

(2) Weighted estimator:

$$\hat{Y} = \sum_{i=1}^{S} \sum_{j=1}^{P_i} \sum_{k=1}^{r_{ij}} Y'_{ijk} = \sum_{i=1}^{S} \sum_{j=1}^{P_i} \sum_{k=1}^{r_{ij}} e_{ijk} Y_{ijk} ,$$

where S, P_i, r_{ij}, and e_{ijk} are defined as before, and

$$Y_{ijk} = \begin{cases} \sum_{\ell=1}^{f_{ijk}} a_{ijk\ell} Y_{ijk\ell} & \text{if } f_{ijk} > 0, \\ 0 & \text{otherwise,} \end{cases}$$

f_{ijk} = number of agricultural tracts in segment k within paper stratum j within land use stratum i.

$Y_{ijk\ell}$ = entire farm value of the variable of interest for tract ℓ within segment k within paper stratum j within land use stratum i, and

$a_{ijk\ell}$ = the weight for tract ℓ within segment k within paper stratum j within land use stratum i. The weight for each tract is always defined and is equal to the ratio of tract acreage to entire farm acreage.

$Y'_{ijk} = e_{ijk} Y_{ijk}$.

$$\hat{\text{var}}(\hat{Y}) = \sum_{i=1}^{S} \sum_{j=1}^{P_i} \sum_{k=1}^{r_{ij}} \frac{(1 - \frac{1}{e_{ij.}})}{(1 - \frac{1}{r_{ij}})} \left\{ Y'_{ijk} - \bar{Y}'_{ij.} \right\}^2 ,$$

the same as for the entire farm estimator.

As mentioned in Apendix A, the above formulas for the variances should be considered as approximations when using procedures 1-3. They are appoximations which probably tend to underestimate the true variance.

APPENDIX C

ENTIRE FARM ESTIMATES AND TEST RESULTS

Table C1: Entire farm estimates and coefficients of variation using 1983 JES data for selected livestock variables in six states.

State	Operational Estimate (000)	Operational CV (%)	Procedure 1 Estimate (000)	Procedure 1 CV (%)	Procedure 2 Estimate (000)	Procedure 2 CV (%)	Procedure 3 Estimate (000)	Procedure 3 CV (%)
TOTAL HOGS								
Georgia	652	21.4	679	21.3	714	22.1	674	21.3
Illinois	6,457	17.0	6,140	17.7	6,147	17.7	6,340	17.6
Iowa	15,293	8.9	15,161	9.3	15,107	9.4	15,675	9.4
Kansas	1,450	20.8	1,332	22.6	1,360	23.2	1,426	23.3
Ohio	1,171	20.8	1,160	21.5	1,144	21.5	1,170	21.6
Wyoming 1/	-	-	-	-	-	-	-	-
Six States	25,022	7.2	24,473	7.5	24,422	7.5	25,285	7.5
SOWS								
Georgia	99	20.2	103	20.6	112	22.9	103	20.6
Illinois	776	16.1	736	16.8	738	16.8	765	16.8
Iowa	1,942	9.4	1,922	9.8	1,908	9.8	1,993	10.3
Kansas	216	23.6	195	26.0	197	26.6	202	25.7
Ohio	155	23.0	163	23.1	160	23.0	163	23.1
Wyoming 1/	-	-	-	-	-	-	-	-
Six States	3,188	7.2	3,119	7.5	3,115	7.5	3,225	7.8

1/ This study did not make estimates for hog variables in Wyoming.

ENTIRE FARM ESTIMATES AND TEST RESULTS

State	Operational		Procedure 1		Procedure 2		Procedure 3	
	Estimate (000)	CV (%)	Estimate (000)	CV (%)	Estimate (000)	CV (%)	Estimate (000)	CV (%)
HOGS PURCHASED								
Georgia	43	57.8	44	61.0	42	59.2	42	59.2
Illinois	561	31.7	570	32.9	560	32.7	574	32.1
Iowa	1,737	18.0	1,857	18.4	1,791	18.5	1,935	18.2
Kansas	318	43.2	313	51.8	352	55.2	377	55.7
Ohio	202	44.2	135	40.4	139	40.1	136	40.2
Wyoming 1/	-	-	-	-	-	-	-	-
Six States	2,861	13.9	2,918	14.6	2,883	14.9	3,063	14.8
EXPECTED FARROWINGS								
Georgia	43	19.1	45	19.4	47	20.7	45	19.3
Illinois	332	17.6	306	19.4	308	19.4	310	19.3
Iowa	985	10.2	969	11.0	952	10.9	1,004	11.7
Kansas	94	26.4	83	29.0	82	29.0	83	28.7
Ohio	67	25.7	71	25.7	69	25.6	71	25.7
Wyoming 1/	-	-	-	-	-	-	-	-
Six States	1,520	7.9	1,475	8.6	1,458	8.5	1,513	9.0
TOTAL CATTLE								
Georgia	1,532	13.5	1,511	14.0	1,498	13.9	1,530	14.1
Illinois	2,627	11.9	2,534	12.6	2,538	12.7	2,561	12.6
Iowa	5,598	7.4	5,520	7.9	5,455	7.9	5,623	8.1
Kansas	5,531	13.7	5,819	14.3	6,315	17.8	5,924	14.3
Ohio	1,764	10.8	1,705	11.1	1,700	11.0	1,720	11.1
Wyoming 1/	1,423	26.2	1,447	28.2	1,450	28.2	1,455	28.1
Six States	18,474	5.6	18,535	6.0	18,957	7.1	18,813	6.0

ENTIRE FARM ESTIMATES AND TEST RESULTS

State	Operational Estimate (000)	Operational CV (%)	Procedure 1 Estimate (000)	Procedure 1 CV (%)	Procedure 2 Estimate (000)	Procedure 2 CV (%)	Procedure 3 Estimate (000)	Procedure 3 CV (%)
MILK COWS								
Georgia	100	47.1	100	47.1	100	47.1	100	47.0
Illinois	284	25.2	258	26.9	252	26.8	255	26.9
Iowa	343	16.8	343	18.2	333	17.1	344	17.7
Kansas	144	29.0	127	31.9	123	31.9	128	31.8
Ohio	407	17.4	383	18.4	377	18.3	383	18.3
Wyoming 1/	5	46.6	2	27.5	2	27.3	2	27.5
Six States	1,284	10.3	1,213	10.9	1,187	10.8	1,213	10.8
STEERS AND HEIFERS								
Georgia	51	25.7	45	24.4	46	24.7	46	24.4
Illinois	789	18.9	797	19.0	798	19.0	805	18.9
Iowa	2,187	13.7	2,145	14.4	2,127	14.6	2,218	14.6
Kansas	1,622	23.9	1,697	24.1	1,728	24.6	1,727	24.0
Ohio	333	17.5	325	17.7	322	17.3	331	17.8
Wyoming	212	27.0	231	27.6	237	27.4	233	27.5
Six States	5,194	10.0	5,240	10.3	5,259	10.5	5,360	10.4
CALVES BORN								
Georgia	500	15.5	494	15.8	491	15.7	497	15.7
Illinois	602	14.2	576	15.7	580	15.6	584	15.7
Iowa	1,320	9.1	1,311	9.8	1,293	9.7	1,326	9.9
Kansas	1,341	15.6	1,372	16.1	1,476	20.0	1,392	16.0
Ohio	391	11.5	384	11.8	384	11.7	385	11.6
Wyoming	554	28.1	557	30.5	557	30.5	561	30.4
Six States	4,707	6.6	4,693	7.1	4,781	8.0	4,745	7.1

ENTIRE FARM ESTIMATES AND TEST RESULTS

Table C2: The relative difference and significance level for entire farm estimates of selected livestock variables from the 1983 JES in six states. The relative difference is 100% (alternative estimate- operational estimate)/ operational estimate.

State	Procedure 1		Procedure 2		Procedure 3	
	Relative difference (%)	Significance level	Relative difference (%)	Significance level	Relative difference (%)	Significance level
TOTAL HOGS						
Georgia	4.2	.03	9.6	.14	3.4	.08
Illinois	-4.9	.26	-4.8	.26	-1.8	.68
Iowa	-0.9	.70	-1.2	.58	2.5	.35
Kansas	-8.1	.45	-6.2	.60	-1.6	.90
Ohio	-1.0	.88	-2.3	.73	-0.1	.99
Wyoming 1/	-	-	-	-	-	-
Six States	-2.2	.25	-2.2	.25	1.1	.62
SOWS						
Georgia	4.8	.12	13.2	.17	4.7	.14
Illinois	-5.2	.26	-4.9	.28	-1.5	.77
Iowa	-1.0	.67	-1.8	.43	2.6	.45
Kansas	-9.6	.42	-8.6	.48	-6.7	.60
Ohio	5.0	.02	3.0	.19	5.2	.03
Wyoming 1/	-	-	-	-	-	-
Six States	-2.2	.29	-2.3	.25	1.2	.65

1/ This study did not make estimates for hog variables in Wyoming.

ENTIRE FARM ESTIMATES AND TEST RESULTS

State	Procedure 1		Procedure 2		Procedure 3	
	Relative difference (%)	Significance level	Relative difference (%)	Significance level	Relative defference (%)	Significance level
HOGS PURCHASED						
Georgia	2.5	.66	-2.4	.39	-2.5	.36
Illinois	1.5	.73	-0.3	.95	2.3	.63
Iowa	6.9	.05	3.1	.32	11.4	.02
Kansas	-1.6	.94	10.5	.73	18.6	.57
Ohio	-33.3	.35	-31.1	.38	-32.8	.36
Wyoming 1/	-	-	-	-	-	-
Six States	2.0	.62	0.8	.87	7.1	.19
EXPECTED FARROWINGS						
Georgia	5.1	.17	9.6	.21	4.9	.21
Illinois	-7.7	.20	-7.2	.25	-6.4	.30
Iowa	-1.6	.53	-3.4	.13	1.9	.63
Kansas	-11.1	.43	-12.5	.37	-11.6	.42
Ohio	6.2	.01	3.3	.13	5.6	.03
Wyoming 1/	-	-	-	-	-	-
Six States	-3.0	.19	-4.1	.06	0.5	.87
TOTAL CATTLE						
Georgia	-1.4	.68	-2.2	.50	-0.2	.97
Illinois	-3.5	.23	-3.4	.14	-2.5	.40
Iowa	-1.4	.63	-2.5	.35	0.5	.89
Kansas	5.2	.07	14.2	.15	7.1	.02
Ohio	-3.4	.27	-3.6	.21	-2.5	.41
Wyoming	1.7	.72	1.9	.67	2.3	.62
Six States	3.0	.81	2.6	.41	1.8	.23

ENTIRE FARM ESTIMATES AND TEST RESULTS

State	Procedure 1		Procedure 2		Procedure 3	
	Relative difference (%)	Significance level	Relative difference (%)	Significance level	Relative difference (%)	Significance level

MILK COWS

Georgia	0.1	.32	0.0	.99	-0.1	.32
Illinois	-9.3	.27	-11.3	.17	-10.2	.22
Iowa	-0.1	.99	-2.8	.59	0.4	.94
Kansas	-11.8	.38	-14.7	.27	-11.1	.42
Ohio	-5.8	.28	-7.5	.16	-5.9	.28
Wyoming	-65.0	.16	-64.8	.16	-64.6	.16
Six States	-5.5	.10	-7.5	.02	-5.5	.10

STEERS AND HEIFERS

Georgia	-11.1	.44	-10.4	.47	-10.1	.48
Illinois	1.0	.52	1.2	.33	2.0	.19
Iowa	-1.9	.66	-2.8	.54	1.4	.79
Kansas	4.6	.24	6.5	.34	6.5	.13
Ohio	-2.6	.60	-3.3	.38	-0.8	.89
Wyoming	9.1	.04	12.1	.03	9.9	.02
Six States	0.9	.70	1.2	.66	3.2	.24

CALVES BORN

Georgia	-1.2	.63	-1.8	.47	-0.6	.83
Illinios	-4.3	.27	-3.6	.28	-3.5	.46
Iowa	-0.7	.85	-2.0	.52	0.5	.89
Kansas	2.3	.53	10.1	.35	3.8	.32
Ohio	-1.9	.55	-1.7	.59	-1.6	.60
Wyoming	0.6	.90	0.5	.91	1.2	.81
Six States	-0.3	.86	1.6	.63	0.8	.65

APPENDIX D

WEIGHTED ESTIMATES AND TEST RESULTS

Table D1: Weighted estimates and coefficients of variation using 1983 JES data for selected livestock variables in six states.

State	Operational		Procedure 1		Procedure 2		Procedure 3	
	Estimate (000)	CV (%)	Estimate (000)	CV (%)	Estimate (000)	CV (%)	Estimate (000)	CV (%)
TOTAL HOGS								
Georgia	925	15.2	913	17.5	974	20.2	962	17.9
Illinois	5,646	10.2	5,453	10.9	5,276	10.3	5,725	10.9
Iowa	14,988	5.8	14,471	6.0	14,647	6.2	15,154	6.1
Kansas	1,075	18.4	1,092	20.0	1,098	21.9	1,132	20.2
Ohio	1,682	12.4	1,605	12.5	1,604	12.6	1,620	12.6
Wyoming 1/	-	-	-	-	-	-	-	-
Six States	24,316	4.5	23,535	4.7	23,600	4.7	24,593	4.7
SOWS								
Georgia	135	13.8	129	14.8	134	17.1	135	15.2
Illinois	666	10.9	640	12.0	618	11.4	671	12.2
Iowa	1,835	6.5	1,767	6.9	1,779	6.9	1,856	7.0
Kansas	142	20.2	142	22.1	144	24.3	145	21.4
Ohio	226	14.2	224	14.4	222	14.3	225	14.3
Wyoming 1/	-	-	-	-	-	-	-	-
Six States	3,005	4.9	2,901	5.3	2,896	5.2	3,033	5.3

1/ Wyoming does not make weighted estimates for any variables.

WEIGHTED ESTIMATES AND TEST RESULTS

State	Operational Estimate (000)	Operational CV (%)	Procedure 1 Estimate (000)	Procedure 1 CV (%)	Procedure 2 Estimate (000)	Procedure 2 CV (%)	Procedure 3 Estimate (000)	Procedure 3 CV (%)

HOGS PURCHASED

State	Operational Estimate (000)	Operational CV (%)	Procedure 1 Estimate (000)	Procedure 1 CV (%)	Procedure 2 Estimate (000)	Procedure 2 CV (%)	Procedure 3 Estimate (000)	Procedure 3 CV (%)
Georgia	112	57.9	124	66.6	156	73.7	135	67.0
Illinois	687	14.7	725	15.4	724	16.1	768	15.5
Iowa	2,232	13.4	2,384	13.8	2,354	14.0	2,507	14.0
Kansas	320	33.7	352	37.7	366	39.2	363	39.1
Ohio	293	21.6	254	19.7	263	20.3	254	19.6
Wyoming 1/	-	-	-	-	-	-	-	-
Six States	3,644	9.5	3,838	10.0	3,863	10.3	4,027	10.2

EXPECTED FARROWINGS

State	Operational Estimate (000)	Operational CV (%)	Procedure 1 Estimate (000)	Procedure 1 CV (%)	Procedure 2 Estimate (000)	Procedure 2 CV (%)	Procedure 3 Estimate (000)	Procedure 3 CV (%)
Georgia	64	14.5	60	15.5	61	17.0	63	15.9
Illinois	318	11.9	304	13.4	293	12.7	317	13.6
Iowa	884	6.8	855	7.3	858	7.3	896	7.3
Kansas	72	24.6	73	27.9	74	30.8	74	26.4
Ohio	106	14.9	105	15.1	104	14.9	106	15.0
Wyoming 1/	-	-	-	-	-	-	-	-
Six States	1,444	5.2	1,398	5.7	1,390	5.6	1,456	5.7

TOTAL CATTLE

State	Operational Estimate (000)	Operational CV (%)	Procedure 1 Estimate (000)	Procedure 1 CV (%)	Procedure 2 Estimate (000)	Procedure 2 CV (%)	Procedure 3 Estimate (000)	Procedure 3 CV (%)
Georgia	1,713	7.9	1,707	8.2	1,706	8.0	1,741	8.1
Illinois	2,555	6.7	2,548	6.9	2,571	7.1	2,612	6.9
Iowa	5,293	4.4	5,124	4.8	5,097	4.7	5,250	4.8
Kansas	4,960	5.2	5,129	5.6	5,115	5.4	5,209	5.6
Ohio	1,846	6.5	1,838	6.6	1,857	6.6	1,856	6.5
Wyoming 1/	-	-	-	-	-	-	-	-
Six States	16,367	2.6	16,346	2.8	16,346	2.7	16,669	2.8

WEIGHTED ESTIMATES AND TEST RESULTS

State	Operational Estimate (000)	Operational CV (%)	Procedure 1 Estimate (000)	Procedure 1 CV (%)	Procedure 2 Estimate (000)	Procedure 2 CV (%)	Procedure 3 Estimate (000)	Procedure 3 CV (%)
MILK COWS								
Georgia	95	37.0	90	39.6	88	40.0	90	39.3
Illinois	272	18.6	269	19.1	264	19.0	272	19.1
Iowa	289	12.8	285	13.2	287	13.2	289	13.2
Kansas	217	43.2	225	48.2	211	44.2	228	48.3
Ohio	462	11.1	457	11.3	466	11.4	460	11.3
Wyoming 1/	-	-	-	-	-	-	-	-
Six States	1,336	9.7	1,326	10.6	1,316	9.8	1,339	10.6
STEERS AND HEIFERS								
Georgia	80	13.0	84	13.3	83	13.2	88	13.5
Illinois	818	14.4	836	14.4	857	14.5	854	14.3
Iowa	1,841	8.1	1,717	8.3	1,711	8.3	1,778	8.4
Kansas	1,357	12.3	1,464	13.4	1,441	12.2	1,492	13.3
Ohio	311	11.1	323	11.6	319	11.2	327	11.5
Wyoming 1/	-	-	-	-	-	-	-	-
Six States	4,406	5.8	4,424	6.2	4,411	5.9	4,538	6.2
CALVES BORN								
Georgia	550	9.6	542	9.9	546	9.7	551	9.8
Illinois	580	7.0	573	7.4	578	7.8	589	7.6
Iowa	1,325	5.1	1,305	5.7	1,295	5.4	1,332	5.7
Kansas	1,262	5.3	1,260	5.4	1,250	5.4	1,278	5.4
Ohio	412	7.6	413	7.7	420	7.9	417	7.7
Wyoming 1/	-	-	-	-	-	-	-	-
Six States	4,130	2.9	4,093	3.1	4,091	3.0	4,166	3.1

WEIGHTED ESTIMATES AND TEST RESULTS

Table D2: The relative difference and significance level for weighted estimates of selected variables from the 1983 JES in six states. The relative difference is 100% (test estimate-operational estimate) /operational estimate.

State	Procedure 1		Procedure 2		Procedure 3	
	Relative difference (%)	Significance level	Relative difference (%)	Significance level	Relative difference (%)	Significance level
TOTAL HOGS						
Georgia	-1.2	.83	5.3	.58	4.0	.57
Illinois	-3.4	.45	-6.6	.11	1.4	.77
Iowa	-3.5	.08	-2.3	.18	1.1	.60
Kansas	1.5	.76	2.1	.74	5.3	.38
Ohio	-4.6	.45	-4.6	.46	-3.7	.56
Wyoming 1/	-	-	-	-	-	-
Six States	-3.2	.06	-2.9	.06	1.1	.53
SOWS						
Georgia	-4.8	.52	-1.4	.88	-0.1	.99
Illinois	-3.9	.41	-7.2	.09	0.8	.87
Iowa	-3.7	.07	-3.0	.08	1.1	.62
Kansas	-0.6	.93	0.8	.92	2.0	.76
Ohio	-1.0	.83	-2.1	.67	-0.5	.92
Wyoming 1/	-	-	-	-	-	-
Six States	-3.4	.05	-3.6	.02	0.9	.63

1/ Wyoming does not make weighted estimates for any variables.

WEIGHTED ESTIMATES AND TEST RESULTS

State	Procedure 1		Procedure 2		Procedure 3	
	Relative difference (%)	Significance level	Relative difference (%)	Significance level	Relative difference (%)	Significance level

HOGS PURCHASED

State	Procedure 1 Relative difference (%)	Procedure 1 Significance level	Procedure 2 Relative difference (%)	Procedure 2 Significance level	Procedure 3 Relative difference (%)	Procedure 3 Significance level
Georgia	10.5	.56	39.3	.40	20.2	.41
Illinois	5.5	.14	5.4	.29	11.9	.01
Iowa	6.8	.01	5.5	.01	12.3	.01
Kansas	9.8	.31	14.4	.28	13.3	.30
Ohio	-13.1	.38	-10.2	.50	-13.1	.38
Wyoming 1/	-	-	-	-	-	-
Six States	5.3	.01	6.0	.03	10.5	.01

EXPECTED FARROWINGS

State	Procedure 1 Relative difference (%)	Procedure 1 Significance level	Procedure 2 Relative difference (%)	Procedure 2 Significance level	Procedure 3 Relative difference (%)	Procedure 3 Significance level
Georgia	-5.9	.45	-3.9	.67	-1.0	.90
Illinois	-4.5	.39	-8.0	.09	-0.3	.95
Iowa	-3.3	.10	-3.0	.10	1.4	.55
Kansas	1.5	.84	3.5	.73	2.8	.67
Ohio	-0.7	.89	-2.2	.67	-0.3	.96
Wyoming 1/	-	-	-	-	-	-
Six States	-3.2	.07	-3.7	.03	0.8	.67

TOTAL CATTLE

State	Procedure 1 Relative difference (%)	Procedure 1 Significance level	Procedure 2 Relative difference (%)	Procedure 2 Significance level	Procedure 3 Relative difference (%)	Procedure 3 Significance level
Georgia	-0.4	.84	-0.4	.83	1.7	.35
Illinois	-0.3	.86	0.6	.73	2.2	.18
Iowa	-3.2	.14	-3.7	.04	-0.8	.73
Kansas	3.4	.12	3.1	.17	5.0	.03
Ohio	-0.4	.78	0.6	.69	0.5	.73
Wyoming 1/	-	-	-	-	-	-
Six States	-0.1	.90	-0.1	.90	1.8	.09

WEIGHTED ESTIMATES AND TEST RESULTS

State	Procedure 1		Procedure 2		Procedure 3	
	Relative difference (%)	Significance level	Relative difference (%)	Significance level	Relative difference (%)	Significance level
MILK COWS						
Georgia	-5.9	.54	-8.1	.40	-5.2	.60
Illinois	-1.0	.70	-2.9	.28	-0.1	.99
Iowa	-1.6	.59	-1.0	.79	-0.2	.95
Kansas	3.4	.75	-2.7	.73	4.8	.67
Ohio	-1.0	.68	0.9	.73	-0.4	.87
Wyoming 1/	-	-	-	-	-	-
Six States	-0.8	.73	-1.5	.44	0.2	.92
STEERS AND HEIFERS						
Georgia	5.5	.01	3.4	.10	9.9	.01
Illinois	2.2	.03	4.8	.08	4.4	.01
Iowa	-6.7	.07	-7.0	.04	-3.4	.38
Kansas	7.9	.03	6.2	.11	9.9	.01
Ohio	3.8	.01	2.5	.13	5.0	.01
Wyoming 1/	-	-	-	-	-	-
Six States	0.4	.83	0.1	.95	3.0	.14
CALVES BORN						
Georgia	-1.5	.50	-0.6	.78	0.1	.95
Illinois	-1.2	.52	-0.3	.86	1.5	.48
Iowa	-1.5	.52	-2.3	.27	0.5	.85
Kansas	-0.1	.97	-0.9	.76	1.3	.66
Ohio	0.2	.90	1.9	.28	1.1	.44
Wyoming 1/	-	-	-	-	-	-
Six States	-0.9	.48	-0.9	.42	0.9	.49

APPENDIX E

WEIGHTED NONOVERLAP ESTIMATES AND TEST RESULTS

Table E1: Weighted nonoverlap estimates and coefficients of variation using 1983 JES data for selected livestock variables in six states.

State	Operational		Procedure 1		Procedure 2		Procedure 3	
	Estimate (000)	CV (%)	Estimate (000)	CV (%)	Estimate (000)	CV (%)	Estimate (000)	CV (%)
TOTAL HOGS								
Georgia	483	21.7	455	25.9	466	28.3	484	27.1
Illinois	1,428	13.3	1,436	14.7	1,367	14.2	1,519	15.0
Iowa	2,861	13.6	2,683	14.8	2,732	15.1	2,832	14.9
Kansas	213	23.2	218	24.5	212	23.7	221	24.0
Ohio	640	18.6	619	18.6	618	18.3	619	18.5
Wyoming 1/	-	-	-	-	-	-	-	-
Six States	5,626	8.3	5,411	8.9	5,395	9.1	5,674	9.0
SOWS								
Georgia	72	19.6	64	20.6	61	18.6	68	22.3
Illinois	176	15.4	178	16.4	171	16.1	188	16.4
Iowa	438	15.8	415	17.3	420	17.3	435	17.1
Kansas	37	27.0	35	26.6	36	36.1	37	26.1
Ohio	94	22.0	97	21.9	97	21.5	97	21.7
Wyoming 1/	-	-	-	-	-	-	-	-
Six States	817	9.7	789	10.4	786	10.4	825	10.3

1/ Wyoming does not make weighted estimates for any variables.

WEIGHTED NONOVERLAP ESTIMATES AND TEST RESULTS

State	Operational		Procedure 1		Procedure 2		Procedure 3	
	Estimate (000)	CV (%)	Estimate (000)	CV (%)	Estimate (000)	CV (%)	Estimate (000)	CV (%)
HOGS PURCHASED								
Georgia	90	71.4	97	80.4	128	85.4	103	80.7
Illionis	251	22.4	250	24.0	238	24.3	268	24.0
Iowa	381	29.6	392	29.4	384	29.4	403	29.0
Kansas	37	58.6	41	57.3	41	55.0	40	55.5
Ohio	155	33.6	118	28.5	120	30.2	117	28.4
Wyoming 1/	-	-	-	-	-	-	-	-
Six States	914	16.6	899	17.5	910	19.0	932	17.4
EXPECTED FARROWINGS								
Georgia	34	21.3	31	22.4	30	20.6	33	23.9
Illinois	86	20.3	86	21.5	83	21.3	91	21.2
Iowa	215	16.6	206	18.2	210	18.3	216	18.1
Kansas	18	32.2	18	38.5	16	35.5	17	38.5
Ohio	44	22.8	45	22.8	44	22.7	45	22.8
Wyoming 1/	-	-	-	-	-	-	-	-
Six States	398	10.6	385	11.4	383	11.6	401	11.4
TOTAL CATTLE								
Georgia	755	13.0	731	13.5	729	13.3	755	13.3
Illinois	427	13.3	410	14.1	412	14.3	430	14.1
Iowa	1,104	12.4	1,076	13.1	1,058	13.0	1,097	13.2
Kansas	1,110	11.0	1,191	13.4	1,114	12.4	1,204	13.3
Ohio	614	10.0	619	10.3	626	10.5	629	10.3
Wyoming 1/	-	-	-	-	-	-	-	-
Six States	4,010	5.6	4,027	6.2	3,939	6.0	4,114	6.2

WEIGHTED NONOVERLAP ESTIMATES AND TEST RESULTS

State	Operational Estimate (000)	Operational CV (%)	Procedure 1 Estimate (000)	Procedure 1 CV (%)	Procedure 2 Estimate (000)	Procedure 2 CV (%)	Procedure 3 Estimate (000)	Procedure 3 CV (%)
MILK COWS								
Georgia	18	65.3	9	87.5	8	87.1	10	87.1
Illinois	49	48.2	52	48.8	50	47.7	55	48.5
Iowa	42	35.1	42	35.2	42	35.3	42	35.3
Kansas	9	62.7	11	64.3	10	64.1	11	64.3
Ohio	99	21.8	100	22.3	99	22.3	100	22.2
Wyoming 1/	-	-	-	-	-	-	-	-
Six States	218	17.3	214	17.9	209	17.7	218	18.1
STEERS AND HEIFERS								
Georgia	42	18.2	44	18.7	44	18.7	48	20.5
Illinois	91	18.8	87	19.7	89	20.1	89	19.7
Iowa	340	17.5	329	18.0	328	18.1	334	17.8
Kansas	319	25.4	375	28.7	344	25.9	376	28.6
Ohio	126	17.5	132	18.1	129	17.3	133	17.8
Wyoming 1/	-	-	-	-	-	-	-	-
Six States	919	11.4	966	13.1	934	11.9	980	12.9
CALVES BORN								
Georgia	235	17.1	223	18.1	223	17.7	227	17.8
Illinois	117	14.2	110	15.2	113	15.5	116	15.1
Iowa	304	14.3	296	16.0	288	15.6	303	16.3
Kansas	257	12.1	256	13.6	245	13.4	260	13.5
Ohio	140	12.2	141	12.5	145	13.1	144	12.5
Wyoming 1/	-	-	-	-	-	-	-	-
Six States	1,053	6.7	1,025	7.3	1,013	7.2	1,050	7.3

WEIGHTED NONOVERLAP ESTIMATES AND TEST RESULTS

Table E2: The relative difference and significance level for weighted nonoverlap estimates of selected livestock variables from the 1983 JES in six states. The relative difference is 100% (test estimate-operational estimate) / operational estimate.

State	Procedure 1		Procedure 2		Procedure 3	
	Relative difference (%)	Significance level	Relative difference (%)	Significance level	Relative difference (%)	Significance level
TOTAL HOGS						
Georgia	-5.8	.58	-3.4	.79	0.3	.98
Illinois	0.6	.89	-4.3	.20	6.3	.23
Iowa	-6.2	.11	-4.5	.26	-1.0	.83
Kansas	2.1	.78	-0.7	.90	3.5	.67
Ohio	-3.3	.65	-3.4	.63	-3.4	.64
Wyoming 1/	-	-	-	-	-	-
Six States	-3.8	.13	-4.1	.12	0.9	.77
SOWS						
Georgia	-10.4	.42	-14.3	.25	-4.8	.74
Illinois	1.0	.80	-2.7	.43	6.8	.19
Iowa	-5.3	.18	-4.2	.30	-0.7	.89
Kansas	-3.7	.78	-1.4	.86	-0.1	.99
Ohio	3.2	.01	3.2	.07	2.9	.01
Wyoming 1/	-	-	-	-	-	-
Six States	-3.3	.20	-3.8	.14	1.0	.73

1/ Wyoming does not make weighted estimates for any variables.

WEIGHTED NONOVERLAP ESTIMATES AND TEST RESULTS

State	Procedure 1		Procedure 2		Procedure 3	
	Relative difference (%)	Significance level	Relative difference (%)	Significance level	Relative difference (%)	Significance level
HOGS PURCHASED						
Georgia	8.2	.67	41.8	.42	14.3	.55
Illinois	-0.6	.94	-5.4	.52	6.8	.50
Iowa	2.9	.25	0.8	.35	5.9	.13
Kansas	12.6	.05	11.2	.24	9.2	.13
Ohio	−23.7	.37	−22.5	.40	−24.2	.36
Wyoming 1/	-	-	-	-	-	-
Six States	-1.7	.76	-0.4	.95	2.0	.74
EXPECTED FARROWINGS						
Georgia	-9.9	.46	-13.4	.29	-4.2	.77
Illinois	-0.1	.98	-3.7	.32	4.8	.37
Iowa	-4.5	.27	-2.5	.57	0.4	.94
Kansas	-4.4	.79	-11.8	.42	-5.5	.74
Ohio	2.6	.02	1.1	.28	2.3	.04
Wyoming 1/	-	-	-	-	-	-
Six States	-3.2	.24	-3.7	.18	0.9	.79
TOTAL CATTLE						
Georgia	-3.3	.33	-3.5	.18	-0.1	.98
Illinois	-4.0	.38	-3.4	.52	0.7	.90
Iowa	-2.6	.50	-4.2	.23	-0.7	.87
Kansas	7.3	.13	0.4	.91	8.5	.08
Ohio	0.9	.54	2.0	.39	2.4	.14
Wyoming 1/	-	-	-	-	-	-
Six States	0.4	.83	-1.8	.25	2.6	.19

WEIGHTED NONOVERLAP ESTIMATES AND TEST RESULTS

State	Procedure 1		Procedure 2		Procedure 3	
	Relative difference (%)	Significance level	Relative difference (%)	Significance level	Relative difference (%)	Significance level
MILK COWS						
Georgia	-46.8	.37	-54.1	.29	-45.1	.39
Illinois	4.6	.18	1.1	.58	11.2	.10
Iowa	-0.3	.62	-0.5	.41	-0.4	.52
Kansas	18.7	.18	7.2	.24	18.7	.18
Ohio	0.5	.87	-0.1	.97	1.0	.73
Wyoming 1/	-	-	-	-	-	-
Six States	-1.8	.69	-4.0	.37	0.1	.99
STEERS AND HEIFERS						
Georgia	4.3	.14	4.5	.19	13.9	.04
Illinois	-5.0	.36	-2.7	.69	-2.7	.65
Iowa	-3.3	.33	-1.7	.58	-3.6	.27
Kansas	17.5	.07	7.8	.06	17.9	.06
Ohio	4.3	.02	2.3	.22	5.6	.01
Wyoming 1/	-	-	-	-	-	-
Six States	5.2	.15	1.6	.42	6.7	.06
CALVES BORN						
Georgia	-5.3	.23	-5.3	.15	-3.4	.46
Illinois	-5.6	.29	-3.5	.58	-0.6	.92
Iowa	-2.7	.57	-5.5	.19	-0.4	.95
Kansas	-0.2	.97	-4.5	.30	1.2	.81
Ohio	0.5	.77	3.1	.36	2.4	.24
Wyoming 1/	-	-	-	-	-	-
Six States	-2.6	.24	-3.8	.05	-0.3	.90

APPENDIX F

This appendix explains how the univariate and multivariate test statistics were calculated.

The analysis used paired t-tests to calculate the univariate test statistics.

Suppose $\hat{Y}$ and $\hat{Z}$ are estimated totals for a particular item of interest, using two different estimators. Suppose

$$\hat{Y} = \sum_{i=1}^{S} \sum_{j=1}^{P_i} \sum_{k=1}^{r_{ij}} Y'_{ijk} = \sum_{i=1}^{S} \sum_{j=1}^{P_i} \sum_{k=1}^{r_{ij}} e_{ijk} Y_{ijk} \quad \text{and}$$

$$\hat{Z} = \sum_{i=1}^{S} \sum_{j=1}^{P_i} \sum_{k=1}^{r_{ij}} Z'_{ijk} = \sum_{i=1}^{S} \sum_{j=1}^{P_i} \sum_{k=1}^{r_{ij}} e_{ijk} Z_{ijk} ,$$

where

S = number of land use strata in the state,

P_i = number of paper strata within land use stratum i,

r_{ij} = number of segments within paper stratum j within land use stratum i,

e_{ijk} = expansion factor for segment k in paper stratum j within land use stratum i,

Y_{ijk} = value of the item of interest for segment k within paper stratum j within land use stratum i using one estimator,

Z_{ijk} = value of the item of interest for segment k within paper stratum j within land use stratum i using a different estimator,

$Y'_{ijk} = e_{ijk} Y_{ijk}$ and

$Z'_{ijk} = e_{ijk} Z_{ijk}$.

Let $\hat{D} = \hat{Y} - \hat{Z}$ be the difference between the estimated totals.

Then,

$$\hat{D} = \hat{Y} - \hat{Z} = \sum_{i=1}^{S} \sum_{j=1}^{P_i} \sum_{k=1}^{r_{ij}} e_{ijk} Y_{ijk} - \sum_{i=1}^{S} \sum_{j=1}^{P_i} \sum_{k=1}^{r_{ij}} e_{ijk} Z_{ijk}$$

$$= \sum_{i=1}^{S} \sum_{j=1}^{P_i} \sum_{k=1}^{r_{ij}} e_{ijk} (Y_{ijk} - Z_{ijk})$$

$$= \sum_{i=1}^{S} \sum_{j=1}^{P_i} \sum_{k=1}^{r_{ij}} e_{ijk} d_{ijk}, \text{ where}$$

$d_{ijk} = Y_{ijk} - Z_{ijk}$.

$$\hat{\text{var}}(\hat{D}) = \sum_{i=1}^{S} \sum_{j=1}^{P_i} \sum_{k=1}^{r_{ij}} \frac{\left(1 - \frac{1}{\bar{e}_{ij.}}\right)}{\left(1 - \frac{1}{r_{ij}}\right)} \left\{ d'_{ijk} - \bar{d}'_{ij.} \right\}^2 ,$$

where

$d'_{ijk} = e_{ijk} d_{ijk}$ and

$$\bar{d}'_{ij.} = \sum_{k=1}^{r_{ij}} \frac{d'_{ijk}}{r_{ij}} .$$

$$\widehat{\text{cov}}\,(\hat{D}_{\ell}, \hat{D}_{m}) = \sum_{i=1}^{S} \sum_{j=1}^{P_i} \sum_{k=1}^{r_{ij}} \frac{\left(1 - \frac{1}{\bar{e}_{ij.}}\right)}{\left(1 - \frac{1}{r_{ij}}\right)} \times$$

$$\left\{ d'_{\ell\,(ijk)} - \bar{d}'_{\ell\,(ij.)} \right\} \left\{ d'_{m(ijk)} - \bar{d}'_{m(ij.)} \right\} .$$

If W_{ij} is the entry in row i and column j in the matrix W then $W_{ii} = \widehat{\text{var}}\,(\hat{D}_i)$, i=1, 2, ..., q and

$W_{ij} = W_{ji} = \widehat{\text{cov}}\,(\hat{D}_i, \hat{D}_j)$
i=1, 2, ..., q; j = 1, 2, ..., q, i≠j.

Thus, W is a q x q symmetric matrix.

To test H_o: D is a zero vector us. H_A: at least one component of D is non-zero, compute

$$t^2 = \hat{D}^T W^{-1} \hat{D}.$$

Let $F = \left(\frac{r.. - P. - q + 1}{(r.. - P.)\, q} \right) t^2,$

where $r.. = \sum_{i=1}^{S} \sum_{j=1}^{P_i} r_{ij}$ is the number of segments in the state and $P. = \sum_{i=1}^{S} P_i$ is the number of paper strata. Then F is distributed as an F - statistic with degrees of freedom equal to (q, r.. - P. - q + 1). Reject H_o if F exceeds the tabular value of F. Tabular values of F exist in many statistical references. In case q=1, Hotelling's test reduces to the paired t-test explained earlier.

If $D = Y - Z$ is the population difference between the totals using estimators Y and Z, then to test H_o: $D=0$ vs. H_A: $D \neq 0$, compute

$$t = \frac{\hat{D}}{\sqrt{\hat{var}(\hat{D})}}$$ and reject H_o if t is too large in absolute value.

Tabular values of t exist in most statistical references. The multivariate tests are generalizations of the univariate tests.

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