IMPUTATION METHODS IN THE SAMPLE SURVEY OF LAW ENFORCEMENT AGENCIES

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Introduction

Previous versions of the Sample Survey of Law Enforcement Agencies (SSLEA 1993, 1990) have used a hot deck approach to impute for item nonresponse and a weighting adjustment to account for unit nonresponse. The initial proposed methodology for the 1997 survey used a variety of methods: historical imputation, mean value imputation and ratio imputation. For both unit and item nonresponse, data are available for some items from previous surveys. When possible, the historic data would be carried forward and adjusted for trends in the imputation class. When historic data are not available, either mean value imputation or ratio imputation would be used. This paper applies the initially proposed 1997 methods to the 1993 data set to determine the impact of the changes in imputation and weighting methodology. The paper also discusses the revised methods actually used in the 1997 survey.

Background

The SSLEA is a voluntary mail survey that was first conducted in 1987. The survey sponsor is the Bureau of Justice Statistics (BJS). The SSLEA collects data on personnel, expenditures, salaries, operations, equipment, special programs, and drug enforcement activities of law enforcement agencies. BJS uses the data to produce national estimates for law enforcement agencies.

The 1993 survey used hot deck imputation to impute values for numeric missing items such as requests for service and number of employees by job function. The survey used a nonresponse weighting adjustment to account for unit nonrespondents. Categorical items, such as functions for which the agency has primary

responsibility or types of non-lethal weapons authorized for use by the agency, have little or no nonresponse, so no imputation is done for those variables.

This paper uses the public use data sets available from the National Archive of Criminal Justice Data [http://www.icpsr.umich.edu/NACJD/]. Since this survey deals with public agencies, the Census Bureau's Title 13 confidentiality restrictions do not apply and thus respondents are fully identified by name and geographic location.

The 1993 survey used the 1992 Directory Survey of Law Enforcement Agencies (Directory) as the universe for sample selection. The directory contained 17,315 agencies. 3,269 agencies were selected from the universe to receive SSLEA questionnaires.

There were four sampling strata used in sample selection: Sheriff's Department, Local Police (either county or municipal police), State Police, and Special Police (either at the state or local level). Self-representing (SR) agencies were defined as those that had 100 or more full-time equivalent (FTE) sworn employees, while non self-representing (NSR) agencies were those that had less than 100 FTE sworn employees. FTE sworn employees is defined as (total full-time sworn employees + 0.5*total part-time sworn employees).

All 853 SR agencies were automatically in sample. 747 NSR sample units were allocated to sheriff's departments, leaving 1,669 NSR units to be proportionally allocated between local police and special police. (All state police agencies were SR.) The distinction between SR and NSR agencies is important because the NSR agencies received a shorter version of the SSLEA questionnaire.

831 of the 853 (97%) SR units in sample responded, while 2,197 of the 2,416 (91%) NSR units in sample

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responded. There were 169 numeric variables that were candidates for imputation, but 7 variables were reported by all respondents, so only 162 variables needed imputation. Item imputation rates ranged from a low of 1 for both SR and NSR agencies to a high of 382 (46%) for SR agencies and 960 (44%) for NSR agencies. For further details on imputation counts, see Persely (1995).

Weighting and imputation were done within cells. The cells were based on SR/NSR status of the agency, sampling strata of agency, FTE sworn employees, and population served for all strata except special police. Unit nonrespondents were accounted for by means of a nonresponse adjustment factor applied to the sampling weight.

Missing values were imputed by randomly selecting an agency from the same cell as a donor for the missing item. The imputation was done on a cell-by-cell basis using hot deck imputation.

One of the major problems with the hot deck imputation method as implemented is that relationships between variables other than components of totals are not necessarily preserved, since the hot deck is done on a variable by variable basis. A record needing imputation for multiple missing items may have multiple donors, a different responding agency for each missing item.

As an example, the survey asks for the minimum salary and maximum salary that the agency offers by position. If the agency is unable to provide either figure, the imputed value for the minimum salary could come from one agency, while the imputed value for the maximum salary could come from another agency. There is no guarantee that the donated minimum value would be less than or equal to the donated maximum value.

Another problem with the hot deck methodology is that some numeric variables such as gross salaries and wages are highly correlated with the total number of employees, but the imputation cell categories are very broad. For SR imputation cells, the measure of size (FTE sworn employees) is grouped into the following categories: 100-134, 135-249, 250-499, 500-999, 1000+.

For example, one imputation cell consists of 29 local police agencies with 1,000 or more FTE sworn employees, serving populations of 500,000 or more. 28 of the agencies were able to report gross salaries and wages. However, one agency could not report the figure and needed that item imputed.

The agency that needed imputation had 1,402 FTE sworn employees, with 2,288 total employees. The total number of employees for agencies that reported gross salaries and wages in this imputation cell ranged from 1,613 to 37,499, while the average wage per employee ranged from $35,157 to $77,403. If the smallest agency in this imputation cell is chosen as the donor, the imputed value for gross salaries and wages is $59,402,191, which results in an average wage per employee of $25,962 --- too low based on reported data. If the largest agency in this imputation cell is chosen as the donor, the imputed value for gross salaries and wages is $1,703,743,563, which results in an average wage per employee of $744,643 --- too high based on reported data.

Initial proposed methodology for 1997

Noting that approximately 1/3 of the sample is also in sample for the previous survey, we suggested using historical imputation, even for unit nonrespondents. Since unit nonrespondents would now be included in the file, we would avoid doing a nonresponse weighting adjustment. However, we would now have to impute entire records, which would involve many more variables than the previous methodology, which only imputed missing numeric variables.

We tested our initial proposed methodology on the 1993 public use data set, imputing only when the flag indicated that the respondent's data was imputed. We used the 1990 public use data set (reported data only) as the historic data when applicable. In addition, we created records for the nonrespondent agencies listed in Persely (1995).

For those unit nonrespondents not in the previous survey, we could use employee count information from the 1992 Directory, adjusted for growth trends in the imputation class, while relying on mean value imputation and ratio imputation for missing numeric data, and hot deck imputation to generate all missing categorical data.

The use of imputation to create entire records for unit nonrespondents in business surveys is useful if there is enough auxiliary information from other sources or past occasions. For more discussion, see Chapter 21 of Business Survey Methods. But do we have enough information from the Directory to impute for all unit nonrespondents, whether or not they were in the

previous survey?

Subject matter specialists at BJS and Governments Division at the Census Bureau were concerned that there was too much change in the agencies between surveys, so that historic imputation would not be useful. We looked at correlations between numeric variables reported in both 1990 and 1993, and rates of agreement between categorical variables reported in both years. Of the 106 numeric variables in both surveys, 63 had a correlation coefficient of 0.8 or greater. Of the 207 categorical variables common to both surveys, 119 had an agreement rate of 80 percent or greater.

After linking the 1993 data set to the 1990 data set, we carried forward all reported 1990 data for the 207 categorical variables in both surveys whenever the item was missing in 1993. We imputed employee counts from the 1990 survey and/or the Directory, adjusted for growth trends, whenever employee counts were missing in 1993. Then we imputed for selected numeric variables, such as vehicle counts, salary data, and training hours, using the historic data adjusted for growth trends.

Other numeric variables, such as requests for service, responses to requests for service, gross salaries and wages, are highly correlated with other variables, so we didn't use historic data for those items.

Once we finished the historic imputation, we imputed all other missing numeric data. Mean value imputation was the method most often used. We calculated averages in each imputation cell, then used those averages to replace missing data in each cell. Raking was done if necessary, so that components would add to totals, such as for detailed employee breakdowns.

By using mean value imputation, we don't have to worry about the relationship between minimum salary and maximum salary. The data is edited before imputation, so the average of the minimum salary will always be less than or equal to the average of the maximum salary. If an agency cannot report either figure, we use the averages of the data reported by agencies in the same imputation cell.

Ratio imputation was used when the missing data was highly correlated with another variable. For example, total requests for service is highly correlated with the total number of employees. In each imputation cell, we calculated the average requests for service per employee. If an agency did not report total requests for

service, we used the imputation cell average multiplied by the total number of employees in that agency to generate a value for total requests for service.

Total responses to requests for service is always less than or equal to the total number of requests for service. In each imputation cell, we calculated the average ratio of responses to requests. If an agency did not report total responses, we used the imputation cell average multiplied by the total requests for service to generate a value for total responses.

Ratio imputation was also used to impute gross salaries and wages. To impute gross salaries and wages for the agency with 1,402 sworn FTEs and 2,288 total employees, we calculated the average wage per employee of each agency reporting gross salaries and wages in that imputation cell. Then we calculated the average of the averages, which is $50,428. We multiplied that figure by the total number of employees to get the imputed gross salaries and wages of $115,378,880. The average wage per employee of the imputed data will always be in the range of the reported data under this methodology.

The final imputation step was to generate values for all the other missing categorical variables. This was done only for the unit nonrespondents. Agencies that respond to the survey are able to provide all the categorical data. The questionnaire has several skip patterns, so we decided to use a hot deck approach to ensure that the record would be internally consistent when looking at all the categorical variables. This implementation of the hot deck used **all** answers from a single donor, instead of the item-by-item approach used in 1993.

Since we had to impute 241 entire records for unit nonrespondents, we ended up imputing 463 variables instead of the 162 under the previous method.

One problem we encountered was that even though questions were repeated from one survey to the next, the coding and/or the answer categories were not always the same. To use the 1990 data, considerable time was spent ensuring that the 1990 values were recoded to the 1993 values.

Some of the 1990 data was unusable. For example, both surveys asked what type of residency requirement an agency has for new recruits. However, in 1990 agencies responded that it was within the legal limits of the jurisdiction, within a specified number of miles of the legal limits, or other. In 1993, the agencies were

asked to mark only one of the following: within state, within county, within municipality, within metropolitan area, within specified miles or driving time, or other. It is not clear what an agency's answer for 1993 should be based on a 1990 response, so we were unable to use this data in historic imputation.

Revised proposed methodology for 1997

Due to time constraints, we decided to use a nonresponse weighting adjustment for unit nonrespondents, and only impute numeric variables for item nonrespondents. Subject matter experts in Governments Division at the Census Bureau and at BJS felt that there had been too much change at law enforcement agencies between 1993 and 1997 to use the 1993 data in historic imputation. In addition, there was concern about releasing a data file with entire records imputed for unit nonrespondents. Since identifiers will be included on the data file, anyone could check the records of the unit nonrespondents. If survey nonrespondents find out that we imputed an entire questionnaire and released it in a data set, they might continue to refuse in the future.

The numeric imputations were done using mean value imputation or ratio imputation. This methodology ensured internally consistent records, so relationships between variables were preserved.

Comparing the methodologies

BJS publishes 2 comprehensive reports based on the SSLEA data. One report describes the findings for local police agencies, while the other discusses sheriffs' departments. There are some coding problems with the public use data set, so estimates from the public use data set will not necessarily agree with published estimates. However, we focus on the publication estimates at the national level as a means of studying the impact of the alternative methodologies.

Tables 1 and 2 show the results under the 3 different methodologies for estimates of total employees. All responding agencies in 1993 reported sworn full-time, other full-time, sworn part-time, and other part-time counts. Since no imputation was done, the estimates are the same under the hot deck or the revised proposed methodology. The initial proposed methodology estimates are higher, reflecting the imputation for the 241 unit nonrespondents.

Tables 3 and 4 show the employee detail estimates. Notice that the estimates for female full-time sworn are

shifting somewhat under the initial proposed methodology. This reflects the imputation for the 241 unit nonrespondents.

Estimates of training hours and starting base pay are shown in Tables 5 and 6. Training hours and starting base pay were imputed by cell means under the initial proposed and revised proposed methodologies.

Tables 7 and 8 show estimates of operating expenditures and equipment. Operating expenditures is the sum of gross salaries and wages plus other operating expenditures. Operating expenditures under the revised proposed methodology are a bit lower than under the hot deck for local police. This is mainly due to the improved estimates of gross salaries and wages, as discussed earlier in this paper.

The only other noticeable differences in the estimates are for total dogs and total horses under the initial proposed methodology, again reflecting the 241 unit nonrespondents.

The 241 unit nonrespondents are not random. Follow-up resources were heavily targeted towards getting the large agencies to respond because they would have the most impact on the national level estimates, so the 241 who ended up as nonrespondents tended to be the smaller agencies. They were in imputation cells where the cell mean value of horses or dogs was less than 0.5, so their imputed values tended to be 0. Since we didn't do the nonresponse weighting adjustment under the initial proposed methodology, the weights of the respondents were a bit lower, so the national estimates are lower.

Results

The revised proposed methodology yields improved imputations for this survey. The hot deck was ignoring relationships between variables, sometimes producing records that weren't reasonable.

It is questionable whether or not we have enough historic data to impute entire records for unit nonrespondents. Since the survey is conducted every 3 to 4 years and has not used historic imputation in the past, the historic data that we have is not in a format that can be easily used for future surveys.

We expect that using mean value imputation and ratio imputation to impute missing numeric data on the 1997 survey will produce internally consistent records, while the results from this paper suggest that national

estimates won't be adversely affected by the change in imputation methodology.

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Table 1. Total Employees for Local Police

Method	Sworn Full-time	Other Full-time	Sworn Part-time	Other Part-time	Sworn Full-time Males	Sworn Full-time Females
Hot Deck	373,208	100,377	28,151	30,041	340,432	32,776
Initial Proposed	373,281	100,727	27,734	30,075	340,668	32,613
Revised Proposed	373,208	100,377	28,151	30,041	340,553	32,655

Table 2. Total Employees for Sheriffs

Method	Sworn Full-time	Other Full-time	Sworn Part-time	Other Part-time	Sworn Full-time Males	Sworn Full-time Females
Hot Deck	156,135	68,562	11,048	8,531	133,407	22,728
Initial Proposed	156,344	67,784	11,343	8,630	132,302	24,042
Revised Proposed	156,135	68,562	11,048	8,531	133,408	22,727

Table 3. Full-time Sworn Employees by Race and Sex for Local Police

Method	White		Black		Hispanic		Other	
	Male	Female	Male	Female	Male	Female	Male	Female
Hot Deck	280,780	21,221	33,851	8,387	20,586	2,714	5,215	454
Initial Proposed	281,538	21,221	33,286	8,271	20,339	2,667	5,505	454
Revised Proposed	281,163	21,192	33,467	8,317	20,371	2,690	5,552	456

Table 4. Full-time Sworn Employees by Race and Sex for Sheriffs

Method	White		Black		Hispanic		Other	
	Male	Female	Male	Female	Male	Female	Male	Female
Hot Deck	112,554	17,147	11,473	4,150	7,764	1,230	1,616	201
Initial Proposed	111,804	18,025	11,553	4,429	7,377	1,369	1,568	219
Revised Proposed	112,782	17,151	11,574	4,174	7,488	1,212	1,564	190

Table 5. Training and Pay for Local Police

Method	Average Training Hours For New Recruits		Average Starting Base Salary By Position (In Thousands)		
	Class	Field	Chief	Sergeant	Entry-level
Hot Deck	432	258	$34.6	$28.5	$21.3
Initial Proposed	429	245	$34.5	$28.1	$21.2
Revised Proposed	432	255	$34.7	$28.4	$21.3

Table 6. Training and Pay for Sheriffs

Method	Average Training Hours For New Recruits		Average Starting Base Salary By Position (In Thousands)		
	Class	Field	Chief	Sergeant	Entry-level
Hot Deck	372	253	$37.8	$24.7	$19.3
Initial Proposed	370	229	$37.8	$24.6	$19.3
Revised Proposed	370	241	$37.8	$24.7	$19.3

Table 7. Operating Expenditures and Equipment for Local Police

Method	Operating Expenditures	Average Total Capacity of Lockup	Total Dogs	Total Horses	Cars / 100 FTE Sworn
Hot Deck	$24.3 billion	10	5,160	1,160	47
Initial Proposed	$24.2 billion	10	5,039	1,138	47
Revised Proposed	$24.1 billion	10	5,160	1,160	47

Table 8. Operating Expenditures and Equipment for Sheriffs

Method	Operating Expenditures	Average Total Capacity of Lockup	Total Dogs	Total Horses	Cars/100 FTE Sworn
Hot Deck	$10.8 billion	49	2,991	1,000	52
Initial Proposed	$10.7 billion	48	2,956	977	52
Revised Proposal	$10.8 billion	50	2,991	1,000	52