THE 1990 POST-ENUMERATION SURVEY: OPERATIONS AND NEW RESULTS

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1. INTRODUCTION

There exists a long tradition within the Census Bureau of using statistical and demographic methods to evaluate the coverage of the population census. However, for more than a decade, there has existed a political and legal controversy about whether those same methods could or should be used to adjust the census results for the undercount. This controversy led to litigation, which in 1989 led to an agreement between the Department of Commerce, of which the Census Bureau is part, and a coalition of states, cities and organizations led by New York City. According to that agreement, the Census Bureau was to conduct a post-enumeration survey and prepare for an adjustment. The Secretary of Commerce, however, reserved the final decision of whether to certify the original or the adjusted census results as official. Guidelines were published for making that decision. [See Department of Commerce, 1990].

The 1990 Post-Enumeration Survey (PES) was the method chosen to produce Census tabulations for states and local areas corrected for the undercount or overcount of the population. Because of the guidelines, the PES needed to meet several requirements. It needed to produce the estimates to be used to correct the Census no later than May 17, 1991. From these estimates, corrected Census tabulations had to be produced by July 15, 1991. The PES was required to meet high quality standards in terms of missing data, matching errors, and other nonsampling errors. Further, to lessen the possibility of, as well as the appearance of, political or other manipulation of the adjusted Census results, procedures had to be specified before analyzing the data. Finally, the PES was to be judged not simply by its ability to estimate the national population, but by its ability to produce improved estimates for states and local areas.

On July 15, 1991, the Secretary of Commerce announced his decision not to adjust the Census. His reasoning is set forth in the Federal Register (Department of Commerce, 1991). As part of his decision, the Secretary asked the Census Bureau to investigate using the results of the PES to correct the estimates of population it makes each year following a census. These postcensal estimates are used as statistical controls for various demographic surveys and for distributing Federal funds under several programs. Thus the story of the adjustment has two parts: the work conducted before July 15, 1991 designed for possible adjustment of the census and the subsequent work aimed at possible adjustment of the postcensal estimates. Further, the PES also serves the traditional purpose of Census evaluation.

2. PREPARING FOR CENSUS ADJUSTMENT

2.1 Overview of Design

The 1990 PES consisted of two parts. The first part was a sample of the population, known as the P sample. The proportion of the P sample that was included in the Census is an estimate of the proportion of the total population that was included in the Census. The second part consisted of a sample of the Census enumerations and was used to estimate the proportion of erroneous Census enumerations. This sample is known as the E sample. These enumerations were checked against the Census itself to determine the extent of duplication. They were also checked in the field to determine the extent of fictitious enumerations, inclusions by the Census of people born after the Census reference day, and the extent to which people were counted in the wrong location.

The population was divided into poststrata based on geography, race, origin, housing tenure, age and sex. The poststrata were based (roughly) on the following hierarchy:

Region (4)
  North East, South, Midwest, West
Census Division (9)
  New England, Middle Atlantic, South Atlantic, East South Central,
Race (4)
  Black, Non-Black Hispanic, Asian and Pacific Islander, Non-Hispanic Whites and Others,
Place /Size (7)
  Central city of major metropolitan area, central city of other large metropolitan area, etc.
Housing Tenure (2)
  Owner, Non-owner
Age (6)
  0-9, 10-19, 20-29, 30-44, 45-64, 65 and over
Sex (2)
  Male, Female

In general, regional differences were preserved over differences between Blacks and Hispanics, Place/Size differences were preserved over housing tenure. Asian and Pacific Islanders were combined with Non-Hispanic Whites for Divisions without separate Asian poststrata. After combining to reduce the number of small cells, the first five criteria defined 116 poststrata groups, including a special group for American Indians living on Indian land. The poststrata groups are listed in Hogan (1992). Each of the 116 poststrata groups was subdivided into the six age and two sex categories to produce 1392 poststrata.

The dual-system model used to estimate the true population classifies each person as being either included or not in the Census enumeration, as well as being either included or not in the PES.

	CENSUS ENUMERATION		
PES	In	Out	Total
In	N_{11}	N_{12}	N_{1+}
Out	N_{21}	N_{22}	N_{2+}
Total	N_{+1}	N_{+2}	N_{++}

All cells are, in theory, observable except for N_{22}, and any of the totals that include N_{22}. The model assumes independence between inclusion in the Census and the PES. This means that the probability of being in the ij^{th} cell, p_{ij}, is the product of the marginal probabilities, $p_{i+}p_{+j}$. With this assumption, the estimate of the total population, N_{++}, is the PES total (N_{+1}) times the Census total (N_{+1}) divided by the number in both (N_{11}). This is called the dual-system estimator (DSE).

In order to estimate the cells of the dual-system model, the PES conducted an independent listing of each sample block, an initial interview, an initial match to the Census, a followup interview of problem cases, and a final match. The estimation steps included missing-data adjustment, weighting and dual-system estimation. These steps are discussed in detail below.

After computing the estimates for all poststrata, the estimated population can be compared to the Census count. The ratio of the estimate to the Census count is called the adjustment factor. A regression smoothing model was used to reduce the variance of the factors. The results of this process were applied to the Census figures to form a synthetic estimate at the lowest level of Census geography, the block. The same poststrata were used for both the dual-system estimation and the synthetic distribution.

2.2 Sampling, Listing and Interviewing

The primary sampling unit for the 1990 PES was the block cluster composed of either a block or a collection of blocks. A sample of 5290 block clusters was chosen. The same blocks were sampled for both the P sample and the E sample. The P sample consisted of all people living in the sample blocks at the time of the PES interview. The E sample consisted of all Census enumerations coded to the sample blocks, whether or not they actually belonged there. The PES sample excluded people living in institutions (jails, nursing homes), military living in barracks or on ships, and people living in homeless shelters or on the street.

The PES household interviewing was scheduled to start on June 25. However, Census nonresponse followup was still being conducted in many areas. Therefore, the PES interviewing had to be delayed. The end of interviewing was shifted accordingly. PES interviewing was complete in most areas by the end of July and finished everywhere by early September. During September, nonresponse cases were sent back to the field to be interviewed by permanent Census Bureau interviewers. This was done in all areas with an initial nonresponse rate of more than two percent.

Table 1 gives the results of P-sample interviewing. The final noninterview rate was less than two percent. However, about five percent of the interviews were not with a member of the household, and were considered to be of questionable quality.

Table 1. Initial PES Interviews by Outcome: Occupied Units

	Number	Percent
Total	143818	100.0
Interviews		
Household Member	134808	93.7
Other	6745	4.7
Non-Interviews	2265	1.6

2.3 Matching

To determine whether a person in the P sample was enumerated in the Census, one needs to match the P sample records to the Census records, which are indexed only by geographic location. P-sample cases were allowed to match census enumerations within the sample block and a set of surrounding blocks. These blocks are referred to as the search area. The first stage in matching was done by a computer matching system that the Census Bureau had developed over the decade. [See Jaro (1989)]. Computer matching used data on the individual characteristics and address information the Census routinely computerizes. In addition, to assist computer matching, the names of the people enumerated in the search area were keyed.

Computer matching required that the Census and the PES files to be largely complete for an area. Computer matching was scheduled to begin on August 9. However, it was delayed until the Census files began to become available. Then, matching proceeded rapidly, and all computer matching was done by the end of September. Computer matching was followed by clerical matching, which reviewed all nonmatches and possible matches.

The computer matching only worked for people who were living in the sample clusters and search areas on Census Day April 1, 1990, since outside these areas, the names were not keyed. Instead, clerks assigned the reported Census Day address to a Census block using maps and computerized address browsing programs. Microfilm copies of the Census questionnaires, which show names, were printed and searched by the clerks, who then assigned a match code.

An initial match code was assigned to all cases before followup. These codes were used in the missing data imputation model to predict enumeration status for cases that could not be interviewed during followup.

Most P-sample cases that were not matched were sent to the field for followup in late November and early December. All whole household nonmatches were sent to followup, since fabrications by PES interviewers tend to fall into this category. Followup also included all nonmatched cases where the initial interview was not with a household member. Nonmatches where other members of the household matched were not sent to followup, provided the initial information was reported by a household member. Not sending these non-matches reduced the followup workload and allowed the limited pool of better trained interviewers to concentrate on the other cases. Although some of the nonmatched people would give different information, there was no guaranty that the information reported in the autumn would be more accurate than that reported the previous summer.

After followup, clerks assigned a final match code. The final match codes provide important information to study the nature of Census errors beyond the question of net undercount.

2.4 Measuring Erroneous Enumerations

The E sample measures the proportion of erroneous Census enumerations. The design considers an enumeration as correct if it is determined not to be a duplicate and if, according to the information provided, the person should have been counted either in the sample block or in one of the surrounding blocks that make up the search area. Erroneous enumerations include: Census duplicates, Census fictitious enumerations, people who were born after Census Day or who died before Census Day, people counted in the wrong location, and Census enumerations with insufficient information to allow both matching and followup reinterview.

The PES also treats as erroneously enumerated any person who was counted by the census in the sample block who did not usually reside in the sample block or the search area on Census Day. An important category of erroneous enumerations were people who moved from outside the search area into the sample block after Census Day and were subsequently counted there in the Census. All such people were considered to be erroneously counted. However, under the search area concept, if they merely moved from one address within the search area to another, they were to be considered correctly enumerated so long as they were counted only once.

The PES used information gathered in the P sample to code the E sample, whenever records from the two samples were linked (matched). For example, if someone in the P sample had indicated that she had not moved, the corresponding E sample record was coded as correctly enumerated. If someone in the P sample indicated that she moved from within the same search area, the corresponding E sample record was also to be coded as correctly enumerated. However, if someone in the P sample indicated that she moved in from outside the search area, the corresponding E sample record would be coded as erroneously enumerated.

Operationally, two records were created for these P-sample movers. A P-sample record reflected their reported residence on Census Day. If they were counted at this address by the Census, they were considered matched. Otherwise, they were treated by the P sample as nonmatched. To facilitate computer matching for the E sample, the PES creates another record for them at the sample address. If the record was linked to a census enumeration at this address, the Census record was to be treated as erroneously enumerated. The only exception was to be if both addresses were within the same search area. Unfortunately errors occurred in applying these rules during computer edits. These are discussed below in Section 3.

Census enumerations that were not linked to a person interviewed in the PES were sent to followup. The information gained during followup allowed the clerks to determine whether the enumeration referred to a real person and whether that person lived at the address on Census Day. For cases where even the address was not included in the PES, the followup interviewers determined where the address actually existed. If it was located outside the search area surrounding the PES sample block, the enumeration was classified as erroneous.

The Census included enumerations with such sparse data that they did not identify a unique individual. A common example are enumerations without names. Such cases could not be matched accurately to a P-sample case, nor could they be sent to followup to determine whether the people were real and lived there on Census Day. These are considered unmatchable and were counted as erroneous enumerations. Thus, no P-sample cases were allowed to "match" these cases. The Census count also includes whole-person imputations, that is cases where the data about an individual were so sparse that another record was substituted. All these cases were classified for PES estimation as not being in the Census. These cases were included in the Census counts when computing net coverage error or applying the adjustment factors.

2.5 Estimation

P-sample cases with missing data occurred because of initial noninterviews or partial interviews and from failed or incomplete followup interviews. In the E sample, noninterviews arose only from the followup since, as noted above, "non-response" Census enumerations are treated as erroneously enumerated. Table 2 gives the level of missing enumeration status. The overall level is low, but as expected, the pattern of PES response roughly parallels the pattern of Census response.

Table 2. Percent Unresolved by Race/Ethnic Group

	P Sample	E Sample
Non-Hispanic White & Other	1.6	0.7
Black	2.5	2.1
Hispanic	2.5	1.8
Asian & Pacific Islander	2.0	1.3

The missing data adjustment began by reweighting response cases to account for the whole-household noninterviews. Reweighting was done within the block cluster where possible. Next, the process imputed any missing demographic characteristics so that each case could be assigned to a poststratum. For example, if race was missing, it was imputed based on the race of other members of the household, or that of neighbors. If age was missing, it was imputed based on the distribution of the response cases with similar other characteristics.

To account for unresolved enumeration status, a large logistic regression model was fit to P-sample data for which enumeration status was observed. This model was used to predict the probability of correctly enumerated versus that of omitted from the Census for unresolved P-sample cases. A separate logistic regression model was fit to resolved E-sample individuals to predict probability of correctly enumerated vs. erroneously enumerated for unresolved E-sample cases. [See Belin and Diffendal (1991) for details.]

Dual-system estimates were made for each of the 1392 poststrata, assuming independence of inclusion in the Census and PES. Note that in the dual-system model, the marginal total, N_{+1}, is the number of distinct and identifiable people in the Census. This differs from the official Census count which includes duplicates, fictitious cases, and other erroneous inclusions as well as imputations. The proportion of census data-defined cases that are erroneous is measured by the E sample. Specifically, the estimator takes the following form within poststrata:

$$\hat{N}_{++} = (N_{+1})\,(N_{1+})\,/N_{11}$$

$$= (N_c\text{-II})\,(1 - \hat{EE}/\hat{N}_e)\,(\hat{N}_p/\hat{M})$$

where

$\hat{N}_{++}$ = Dual-system estimate of the population

$\hat{N}_p$ = Weighted P-sample total (= N_{1+})

N_c = Census Count

II = Number of whole persons Census imputations

$\hat{EE}$ = Weighted estimate of E-sample erroneous enumerations

$\hat{N}_e$ = Weighted E-sample total

$\hat{M}$ = Weighted estimate of P-sample matches (= N_{11})

Note

$$N_{+1} = (N_c - II)(1 - \hat{EE}/\hat{N}_e) .$$

While computing the DSE's, two block clusters were discovered to exert extremely large leverage on the estimates. Leverage in this context was defined as the absolute value of the difference between the weighted number of nonmatches and the weighted number of erroneous enumerations for the cluster. Both of these block clusters were drawn from a special sample of Census blocks where few housing units were expected and low sampling probabilities (and corresponding high sample weights) applied. The possibility of such cluster outliers had been anticipated. Accordingly, both block clusters were down-weighted, and the DSE's recomputed.

The difference between the estimated population, $\hat{N}_{++}$ and the Census count N_c (without removing imputations or erroneous enumerations) estimates the net Census undercount. The ratio of the estimated true population, $\hat{N}_{++}$ to the Census count, N_c, is the adjustment factor.

It was anticipated that many of the 1392 poststrata adjustment factors would have variances too high for them to be useful for adjustment. One way to reduce the variance would be to form fewer poststrata, that is, to assume homogeneity across broader categories. This approach is discussed in Section 3. Instead, for the Census adjustment estimates, a regression smoothing approach was adopted. A regression model was fitted to predict the adjustment poststratum factors in a way that allowed for sampling error. The regression-predicted factor was then "averaged" with the observed factor to form the smoothed factor. The model thus attempted to "borrow strength" from many cells, somewhat in the spirit of a Bayes estimation approach. In more detail, the model was as follows:

$$Y = X\beta + w + e$$

where

Y = Observed adjustment factor by poststratum

X = Matrix of carrier (regression) variables

β = Vector of fixed effects (regression parameters)

w = Model error, assumed $N(0,\sigma^2 I)$

e = Sampling error, assumed $N(0,V)$, where V is the sampling error covariance matrix.

The observations were the adjustment factors for the 1392 poststrata. The model was fit separately for the four Census regions, and a reduced model was used for the special American Indian strata.

The variables used to form the poststrata were also used as predictors. These variables were expressed as indicators. If categories were combined the variables were expressed as proportions. Other variables measured the difficulty in taking the Census. These included the proportion of people enumerated on questionnaires returned by mail, the proportion of Census whole-person substitutions, and the proportion of enumeration conducted using traditional door-to-door enumeration.

The Census adjustment estimates showed a net national undercount of 2.1 percent. Higher undercounts were measured in the South and West and lower undercounts in the North East and Midwest. The levels and patterns of the measured undercounts largely followed expectations. Undercounts tended to be higher for Blacks, Hispanics and Asians, and were high for nearly all nonowner poststrata groups. Low undercounts tended to be seen in suburban areas and small towns. (See Hogan 1991).

Distribution of the estimated undercount geographically below the poststratum level was done by multiplying the poststrata adjustment factors by Census counts for each poststratum in each block in the Census. The block level was used to insure that all subsequent tabulations based on the adjustment are consistent. The Census counts for groups excluded from the PES frame, e.g. the institutional population, remain unchanged.

This process generally did not produce whole numbers of persons. Fractions were rounded either up or down to a whole person, using a controlled rounding procedure that ensured that the poststrata within a block as well as the total for any block were not rounded up or down by more than one. The totals by poststratum for states were controlled to the level of precision of the computer, roughly 10 people. In order to reflect the count adjustment in individual records for the Census blocks, whole person records were imputed using a procedure similar to that used by the Census for other missing data. For overcounts, a "negative" record was imputed.

Had the Census been adjusted based on the PES results, the official count of the resident population would have increased by 5.27 million. That would have made the official resident population of the United States just under 254 million. Of the increase, 1.5 million (29%) would have been Black, 1.2 million (23%) would have been Hispanic, 231 thousand (4.0%) would have been Asian and Pacific Islander, and 99,000 (1.9%) would have been American Indian. The rest were non-Hispanic Whites and other races. These are net numbers. In fact, 6.19 million records would have been added to account for net undercounts and 919,000 records "subtracted" to account for net overcount. After the count adjustment record was imputed, the adjusted files were tabulated. These were completed in time for the July 15 deadline.

3. IMPROVING THE ESTIMATES

There were several criticisms of the approach used in the July Census adjustment estimates. (See Department of Commerce, 1991). In terms of producing alternative undercount estimates for use in the postcensal estimates program, three criticisms were paramount:

1) The use of the smoothing models led to estimates whose true uncertainty was difficult to assess. For example, the smoothing assumed that the variance matrix (V) was known with certainty, when it was actually estimated. The effects of uncertainty in the estimated covariances were of special concern.

2) The poststrata were possibly too heterogeneous, especially geographically, to be suitable for the synthetic estimation of undercount for small areas. For example, Delaware is included in the South region rather than the North East.

3) The direct (unsmoothed) estimates were thought to be biased. The biases of a PES are well documented (See Hogan and Wolter 1988, Mulry and Spencer 1991). Not all errors could be corrected. The bias due to misreporting of Census Day address was unlikely to be corrected over a year after Census Day. Other biases might be reduced, including matching bias.

Two approaches were taken in order to respond to these criticisms. First, new poststrata were developed. This step was designed to increase homogeneity, by forming better poststrata, and, at the same time, to decrease the variance of the direct dual-system estimates by forming fewer poststrata. Second, the basic PES data set was modified to remove some of the bias and to reduce variance.

The alternative poststratification was designed to produce estimates of the relative proportions by state and local areas that did not rely upon statistical smoothing. In forming poststrata, one is faced with two opposing goals. First, one would like each of the poststrata to be as homogeneous as possible. This can be most easily accomplished by forming many, relatively small, poststrata. However, in general, for any fixed overall sample size, more poststrata mean smaller sample sizes within each and higher variance for each of the poststrata. Of course, it is not just the variance of the poststrata that is important, but the variance of the state and local estimates produced. Large poststratum variances can lead to large variances for estimates of interest. Since the goal was to develop fewer as well as more homogeneous poststrata, it was important to choose the stratification variables wisely.

The original 116 poststrata groups were developed well before the Census and the PES were conducted. In forming the new poststrata, the results of both the PES and the Census were known. The original 116 poststrata had been based on a hierarchy in which geographic differences were largely preserved over race and ethnic differences. Differences in place/size were preserved over differences in housing tenure. The results of the PES did not necessarily validate this hierarchy. For example, differences between some place/size categories were often small, while differences between owners and renters were often striking. Divisional differences showed a confusing pattern often obscured by quite high variances.

In developing the new poststrata, there was a limit to the extent that the PES results could be directly used. First, since they were subject to (sometimes quite high) variances, combining groups with similar estimated undercounts is not exactly the same as combining groups with similar true undercounts. General patterns as revealed from statistical analysis did prove useful, however. Further, the existing poststrata groups could not be used to suggest completely new groupings. For example, it could not help in determining whether a different measure of "urbanization" might be superior to that originally used.

Instead, the analysis focused on measures of Census performance derived from the complete Census file, such as mail-return rates and whole-person substitution rates. Measures of crowding, proportion nonhousehold members, item imputation rates and a few other variables also proved helpful. The working assumption was that poststrata defined to be relatively homogeneous with respect to these variables would also be relatively homogeneous with respect to the undercount. The results of this analysis suggested a hierarchy of:

Race (4)
- Black, Non-Black Hispanic, Asian and Pacific Islander, and Non-Hispanic White and Other

Housing Tenure (2)
- Owner, Non-owner

Urbanization (3)
- Urbanized areas with population greater than 250,000
- Other urbanized and urban areas
- Rural

Region (4)
- North East, South, Midwest, West

The separate group for American Indians or reservations was maintained. Appendix Table 1 lists all 51 revised poststrata groups. Considerable research went into deciding whether there was a grouping of states or even counties that was better than the four traditional Census Regions. Although some alternative patterns did emerge, none were consistent across the variables of interest (i.e. mail back rate, allocation rate, etc.). The decision was made to continue to use the traditional four census regions because of their familiarity to users of census products, but to drop the finer breakdown by divisions.

Each new poststrata group is divided by age and sex into estimation poststrata. The Census adjustment estimates used 12 age-sex groups, that is six age groups cross-classified by the two sexes. This scheme had several drawbacks. First and most importantly, it produced far too many cells (1392). A quarter of the original cells contained fewer than 130 P-sample cases; the smallest contained only eight. Research conducted over the summer with the original 116 poststrata groups but with only six age-sex groups showed great advantage over the original scheme (See Hogan and Isaki 1991).

From a demographic point of view, the six age groups were not well chosen. The most glaring problem concerns the group for ages 10 to 19. It seems clear that in terms of lifestyle (mobility, independence, etc.) that a 19 year old has very little in common with a 10 year old. This suggested an alternative age grouping:
0 - 17, 18 - 29, 30 - 49, 50 and over.

Finally, there seemed to be no reason to calculate separate estimates for girls and boys, 0-17. Demographic analysis had never shown a sex difference for this group. The Census adjustment estimates had shown little difference in undercount between these groups. Therefore, rather than the original 12 age-sex groups, the post-censal poststrata have only seven. This gives 357 poststrata rather than 1392.

The restratification was most successful in avoiding the very small sample sizes, which had lead to high variances and difficulties in estimating the covariance matrix. Small poststrata also led to ratio-estimation bias, which could also be reduced with the new postratification.

Since the time that Census adjustment files were produced, the PES data file has been modified in several ways in order to reduce some of the biases and variances. New clerical matching has been conducted on a set of blocks. Also, several computer edits have been applied to the data file.

The 104 block clusters with the highest "leverage" on the PES estimates were reworked by a small group of matching experts. The measure of leverage is the same as was used to downweight the outlier clusters. The matching staff reviewed all aspects of the matching for these block clusters. In general, they applied the same matching rules as were to be used in the production (i.e. November 90 to January 91) matching. For example, they reviewed each case to see if it represented a complete interview. They determined correct Census Day addresses. They searched for new matches (P sample) as well as new duplicates (E sample).

In a few cases, the matching rules were modified. Of particular interest was the definition of search area. The original definition of search area was the sample block and either one ring of surrounding blocks (in urban areas) or two rings (in more rural areas). If applied consistently to both the P sample and E sample, this rule will produce unbiased estimates (in the absence of other errors). See Hogan (1992). Unfortunately, it can also produce estimates with extremely high variances. If the Census incorrectly assigns (misgeocodes) a large group of housing units just outside the search area, the rule will produce either a high number of nonmatches or a high number of erroneous enumerations, depending upon which blocks fell in sample. Over all possible samples, the estimator will balance. However, since mis-assigning large numbers of housing units is a rare event, for any actual sample, one will usually observe either a high number of nonmatches (high measured undercount) or a high number of erroneous enumerations (high measured overcount.).

In the Census adjustment estimates, these effects were smoothed out over an entire region. Without smoothing, the entire effect will be left within a particular poststratum. Therefore, in the rematching, the search area was sometimes expanded by an extra ring if it seemed that strict application of the production rule was the main cause of a cluster's high influence.

A problem was discovered in the computer editing of erroneous enumerations. The PES was designed to treat as erroneously enumerated any person who was counted by the census in the sample block who did not usually reside in the sample block or the search area on Census Day. The PES used information gathered from the P sample to code the E sample, whenever records from the two samples were linked (matched). If a mover was linked to a census enumeration at the sample address, the Census record was to be treated as erroneously enumerated.

Unfortunately, an error occurred in carrying out this step in the Census adjustment estimates. Essentially, the edit was applied to the E sample only if the P sample Census Day ("Mover") record was matched. Otherwise, the E sample record was treated as a correct enumeration. Thus, over 2,000 E sample matches to in-movers that should have been treated as erroneously enumerated were treated as correctly enumerated in the July 1991 PES estimates. Additionally, the edit was incorrectly applied to only part of the entire file. Because of this, over 560 cases were coded as erroneous enumerations when they should have stayed as matches. Correcting these records lowered the estimated net undercount by about 0.4 percent. In addition, there were a few other rather minor edit corrections, as well as an improvement to the missing data imputation program.

4. UNDERCOUNT RATES FOR USE IN THE POST-CENSAL ESTIMATES

4.1 Net Coverage Error

The net result of the work done since July has been to lower the PES estimates of the undercount by about half of a percentage point, from around 2.1 percent to about 1.6 (with a standard error equal to 0.2 for each estimate). This reduction tends to bring PES estimates at the national level more in line with the 1.7 percent undercount estimated by demographic analysis comparison to vital records and other independent data sources. The original production estimates would have added 6.19 million records while "subtracting" 919,000. The new estimate adds 5.45 million records (a decrease of three quarters of a million). However, 1.46 million records are now "subtracted" (an increase of a half million). Again the important issue is the pattern of undercount by area and group.

Table 3. Undercounts by Race/Ethnic Origin by Tenure

	Total	Owner	Non-owner
Non-Hispanic White & Other	0.7	-0.3	3.1
Black	4.6	2.3	6.5
Hispanic	5.0	1.8	7.4
Asian & Pacific Islander	2.4	-1.4	7.0
Reservation Indian	12.2	n/a	n/a

Table 3 gives the corrected results by race and tenure. The undercount for Non-Hispanic Whites and Others is relatively low (less than one percent) while the undercount for Blacks and Hispanics is relatively high (4.5 to 5.0 percent). The undercount rate estimated for Asians lies in between. An interesting pattern emerges when we look at the results by race and tenure. The results seem to show that tenure is as important in explaining undercount as is race. This result, if it is supported by other research, has interesting implications for planning not just the postcensal estimates but the next census. The spread between Asian owners and Asian non-owners is much larger than for other groups. It is probably because Asian non-owners tend to be disproportionately recent immigrants while Asian owners are drawn from more established communities. At this time, one can only speculate whether the difference between tenure groups is due to tenure itself (i.e., renters tend to move more often) or because owners and renters are drawn from different groups.

Appendix Table 1 gives the new undercount estimates for the revised poststrata, together with their estimated standard error. These are the key results for use in the postcensal estimates. The patterns by race and tenure are evident there. There is also a regional pattern, with the undercounts for the West and South being somewhat higher than those for the Northeast and Midwest. The Non-Urban areas often have higher estimated undercounts than the urban areas, but they also often have high standard errors which make interpretation difficult.

A few cells are of particular interest. The estimates for non-Hispanic Whites in urban areas in the North East are both negative, i.e., overcounts of 2.1(standard error = 1.1) and 1.1 (.5). However, these estimations are on the margin of significance at the 95 percent level. These numbers are applied to very large groups which together comprise approximately 20 million people, and produced an estimated overcount of 376,000. Still, comparing these cells to nearby cells does not seem to show that these estimates are far out of line.

The estimates for the individual 357 poststrata tend to show the same general pattern, of course, but are much less stable. Figure 3 shows the distribution of poststrata estimates by race and tenure group. The viewer can easily see that even with fewer poststrata, the directly estimated undercounts are still quite spread.

One of the main interests in the undercounts in terms of the postcensal estimates is for the individual states. Appendix Table 2 gives the production (July 15) state estimate (undercount rate and standard error) and the revised state estimates. The estimated undercount is reduced for all but five states. It falls by more than one percentage point in Tennessee, Delaware, West Virginia, New Mexico and the District of Columbia. The estimated population of California is reduced by over a quarter of a million. At the other extreme, Maryland's estimated undercount rose by 0.3 percent and New Hampshire's increased by 0.5 percent.

Of particular interest is the estimate of relative proportions. Specifically, one can calculate the relative state undercount, i.e. $100*(1- pc_i/pa_i)$ where pc_i is the proportion of total population for state i in the census and pa_i is its proportion in the adjusted population. Figure 1 plots these relative state undercounts for the Census adjustment figures versus the revised figures. They are clearly highly related, as should be expected. Their correlation coefficient is .93. Still, there are important differences between the two series. For example, the most extreme relative undercounts have been brought down by the new estimates.

4.2 Gross Census Errors

The PES was designed to measure the net undercount by group and to provide the data to adjust for that net undercount. It also provides data on the gross Census errors: gross omissions and gross erroneous inclusions. However, one must take care in interpreting these data: some of the measures and concepts are appropriate only when considered in terms of the way they produce net estimates. In addition, all of these data are subject to sampling error, which for some groups and categories, is quite large.

The PES estimates the proportion of the population not enumerated at their correct census day residence. Table 4 gives the distribution of nonmatches by category (for nonmovers).

- N1 Nonmatched person within a household where other people matched
- N2 Nonmatched person within a household where no other person matched, however, the housing unit was included in the Census
- N3 Nonmatched person within a missed housing unit, however other housing units in building were included in the Census
- N4 Nonmatched person living in a building missed by the Census
- L Census processing error (i.e. person listed on a Census questionnaire which was returned but not counted in the Census.)

Table 4. Types of Nonmatches as Percent of Total Resolved Cases

	N1	N2	N3	N4	L
Total	1.8	2.0	0.5	1.3	0.3
Non-Hispanic White & Other	1.3	1.6	0.3	1.3	0.2
Black	4.3	4.7	1.2	1.3	0.4
Hispanic	3.3	2.7	1.4	1.6	1.0
Asian & Pacific Islander	2.6	3.0	0.8	0.6	0.5

Several features are interesting. First, the PES nonmatches include a high proportion of within household omissions. The next feature is the high number of N2's, missed households within enumerated housing units. A missed household within enumerated housing units can happen in different ways. The housing unit could be enumerated as vacant. Another family in the building may have been enumerated in place of the missed household, as sometimes happens in older buildings without clearly marked apartment numbers. The enumerator may have created a fictitious household as a replacement. Another way would be if the enumerator failed to get a complete interview, causing the family to either be imputed in the Census or classified as "Unmatchable." Each of the last three ways would create an erroneous enumeration which would, to some extent, offset the omissions.

Table 5. Distribution of Measured Erroneous Enumerations by Type

	Percent of Total	Percent of EE's
Total EE	5.8	100.0
Duplicate	1.6	28.2
Fictitious	0.2	2.6
Geocoding error	0.3	6.0
Other counting errors	2.2	38.0
Unmatchable	1.2	20.8
Imputed EE's	0.3	4.5

The revised PES data show some 14 million Census erroneous enumerations, which together with 2 million Census imputations are subtracted from the Census counts before applying the dual-system estimator. How should one interpret this number? Table 5 gives the weighted distribution of erroneous enumerations by type. Some 28 percent are Census duplicates. About two and a half percent are estimated fictitious.

The PES estimated that about 6 percent of the erroneous enumerations were people who were enumerated outside the search area, i.e. two or more blocks away. The block counts are off, but if these persons were missed in the correct block (which we do not know), then as blocks are aggregated, the coverage errors cancel.

Most of the "Other Counting Errors" are enumerations of people who moved into the address after Census Day. If they were missed at the correct location, this may be the only place these people were enumerated. This type of error is often, but not always, paired with Census omissions of the actual Census Day residents.

The "Unmatchable" cases represent Census enumerations without names. The PES required sufficient identifying information so that the person could be matched or followed up. Without this information, they were coded "Unmatchable." Many of these enumerations refer to real people who actually lived at the address, although others may be duplicates, fictitious, etc. The PES gives no direct information.

Finally, the PES imputed roughly half a million erroneous enumerations. The imputation program only predicts a probability of the enumeration being erroneous. Summing these probabilities gives an estimate of the number, but no indication of the cause.

Figure 2 plots the percent nonmatches against the percent erroneously enumerated and unmatchable in the Census for the 51 poststrata groups. It includes a reference line plotted with slope 2.0 and intercept of -3 percent. Some of the variability observed here is due to sampling. However, one can see how much the net undercount being measured by the PES is really a function of both nonmatches and erroneous enumerations.

5. CONCLUSION

Perhaps it is still too soon to reach a conclusion about the 1990 PES. The litigation continues over the Census adjustment estimates. The revised estimates are still being evaluated and analyzed in terms of bias and variance. Statisticians still hold different viewpoints. Some results are, however, now clear.

At an operational level, the PES succeeded. Completing all the operations necessary for Census adjustment by July 1991 was a monumental accomplishment. This success demonstrates the operational feasibility of Census adjustment. Still, if similar methodology were to be used in the future, the time frame would probably have to be shortened even further, in order to produce adjusted state numbers by December 2000.

Some of the revisions made since the Census adjustment estimates were produced point the way to improvements for the future. The revised postratification seems to be a great improvement producing more stable estimates with a sharper distinction between groups. This change lessens the need for statistical smoothing but at the same time, may make a smoothing process work better. Correcting the specific errors that were made in 1990 was easy compared to preventing new errors from occurring in any future adjustment process.

The PES is also serving its older function, as a tool of census evaluation. Understanding the importance of housing tenure in undercount will surely help guide future Census outreach activities. Tracing the erroneous enumerations back to the Census operation that produced them will help guide the design of future operations. This work has already begun. The PES can also inform the data users. Press coverage and anecdotal evidence often gave the impression that the 1990 Census was an overall disaster. The results of the PES dispel this impression by putting the undercount in perspective. They allow each user to judge the probable effect of coverage error on a particular use of the data. This, of course, has long been the motivation for conducting coverage evaluation studies.

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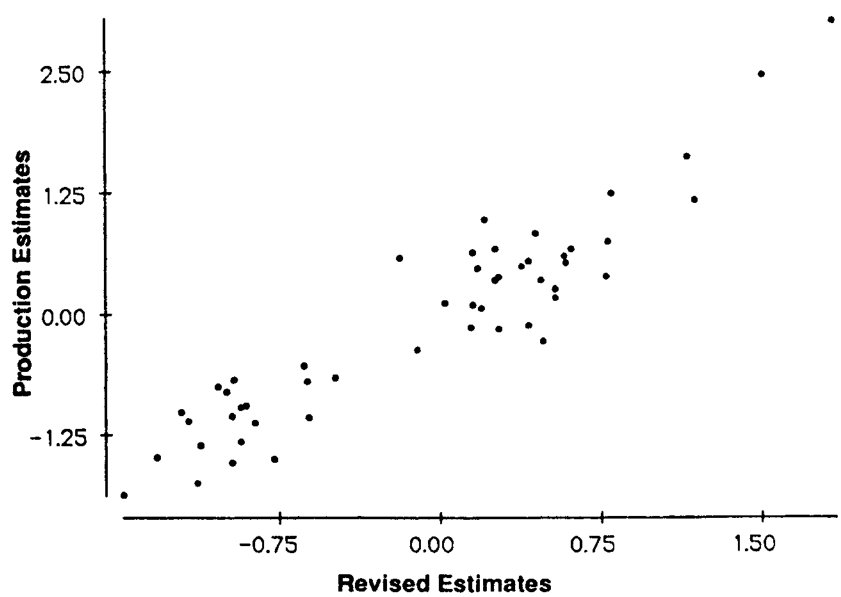
*This paper reports the general results of research undertaken by Census Bureau staff. The views expressed are attributable to the author and do not necessarily reflect those of the Census Bureau.

Appendix Table 1: Estimates for Revised Post-Stratatification

Post-Strata Groups	Percent Undercount					Standard Errors				
	All	NE	S	MW	W	All	NE	S	MW	W
Non-Hispanic White & Other										
Owner										
Large Urbanized Areas		-2.13	0.68	-0.26	-0.34		1.08	0.71	0.39	0.65
Other Urban		-1.08	0.52	-0.10	0.62		0.49	0.42	0.40	0.58
Non-Urban		-0.54	0.18	-0.71	0.29		0.70	0.69	1.18	0.69
Non-owner										
Large Urbanized Areas		1.16	2.56	2.33	3.18		1.39	1.48	1.61	1.62
Other Urban		3.41	3.20	1.23	4.49		1.51	1.74	1.09	1.34
Non-Urban		6.52	6.23	2.85	6.08		4.20	1.71	1.51	1.81
Black										
Owner										
Large Urbanized Areas		1.63	2.16	0.81	6.10		1.91	0.90	0.87	1.91
Other Urban	1.34					0.98				
Non-Urban	3.52					1.90				
Non-owner										
Large Urbanized Areas		8.37	6.27	5.99	9.96		1.61	1.90	1.68	2.72
Other Urban	4.15					1.18				
Non-Urban	4.62					5.33				
Non-Black Hispanic										
Owner										
Large Urbanized Areas		0.67	2.53	-4.33	2.89		4.45	0.90	2.58	0.87
Other Urban	0.94									
Non-Urban	2.73					1.64				
Non-owner						2.69				
Large Urbanized Areas		6.72	9.34	6.64	5.91		3.51	2.59	3.26	1.84
Other Urban	6.60					2.74				
Non-Urban	15.80					5.01				
Asian & Pacific Islander										
Owner	-1.45					1.50				
Non-owner	6.96					2.52				
American Indians on Reservations	12.22					4.73				

Figure 1: State Proportions: Production and Revised Estimates
Percent Relative Undercount



Appendix Table 2: Undercount Rates by State: Adjustment and Revised

Name	Original Rate	Original se	Revised Rate	Revised se	Name	Original Rate	Original se	Revised Rate	Revised se
Alabama	2.5	0.4	1.8	0.3	Montana	2.8	0.5	2.4	0.5
Alaska	1.9	0.4	2.0	0.4	Nebraska	1.0	0.4	0.6	0.4
Arizona	3.3	0.5	2.4	0.5	Nevada	2.4	0.5	2.3	0.4
Arkansas	2.2	0.4	1.7	0.3	New Hampshire	0.6	0.5	0.8	0.5
California	3.7	0.4	2.7	0.4	New Jersey	1.4	0.5	0.6	0.6
Colorado	2.4	0.5	2.1	0.4	New Mexico	4.5	0.5	3.1	0.5
Connecticut	0.6	0.6	0.6	0.4	New York	1.7	0.5	1.5	0.6
Delaware	3.0	0.4	1.8	0.4	North Carolina	2.7	0.4	1.8	0.3
DC	5.0	0.5	3.4	0.9	North Dakota	1.4	0.5	0.7	0.5
Florida	2.6	0.4	2.0	0.4	Ohio	0.8	0.4	0.7	0.4
Georgia	2.3	0.4	2.1	0.3	Oklahoma	2.1	0.4	1.8	0.3
Hawaii	2.5	0.5	1.9	0.8	Oregon	1.9	0.4	1.9	0.4
Idaho	2.8	0.5	2.2	0.4	Pennsylvania	0.6	0.5	0.3	0.5
Illinois	1.4	0.4	1.0	0.4	Rhode Island	0.3	0.6	0.1	0.6
Indiana	0.7	0.4	0.5	0.4	South Carolina	2.9	0.4	2.0	0.4
Iowa	1.1	0.5	0.4	0.4	South Dakota	1.5	0.5	1.0	0.5
Kansas	1.2	0.4	0.7	0.4	Tennessee	2.7	0.4	1.7	0.3
Kentucky	2.2	0.4	1.6	0.4	Texas	3.2	0.4	2.8	0.4
Louisiana	2.6	0.4	2.2	0.4	Utah	1.9	0.5	1.7	0.5
Maine	1.0	0.6	0.7	0.6	Vermont	1.4	0.7	1.1	0.8
Maryland	1.8	0.4	2.1	0.4	Virginia	2.6	0.4	2.0	0.4
Massachusetts	0.4	0.5	0.5	0.5	Washington	2.4	0.4	1.8	0.4
Michigan	1.2	0.4	0.7	0.4	West Virginia	2.6	0.4	1.4	0.4
Minnesota	1.0	0.4	0.4	0.4	Wisconsin	0.7	0.4	0.6	0.4
Mississippi	2.2	0.4	2.1	0.4	Wyoming	2.7	0.5	2.2	0.4
Missouri	1.3	0.4	0.6	0.4					

Figure 2: Percent Not Matched vs Percent Erroneous Enumerations
Revised Poststratum Groups