Survey Methodology, June 1988
Vol. 14, No. 1, pp. 71–86
Statistics Canada



# The 1986 Test of Adjustment Related Operations in Central Los Angeles County

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ABSTRACT

As part of the planning for the 1990 Decennial Census, the Census Bureau investigated the feasibility of adjusting the census for the estimated undercount. A test census was conducted in Central Los Angeles County, in a mostly Hispanic area, in order to test the timing and operational aspects of adjusting the Census using a post-enumeration survey (PES). This paper presents the methodology and the results in producing a census that is adjusted for the population missed by the enumeration. The methodology used to adjust the test census included the sample design, dual-system estimation and small area estimation. The sample design used a block sample with blocks stratified by race/ethnicity. Matching was done by the computer with clerical review and resolution. The dual-system estimator, also called the Petersen estimator or capture-recapture, was used to estimate the population. Because of the nature of the census enumeration, corrections were made to the census counts before using them in the dual-system estimator. Before adjusting the small areas, a regression model was fit to the adjustment factor (the dual-system estimate divided by the census count) to reduce the effects of sampling variability. A synthetic estimator was used to carry the adjustment down to the block level. The results of the dual-system estimates are presented for the test site by the three major race/ethnic groups (Hispanic, Asian, Other) by tenure, by age and by sex. Summaries of the small area adjustments of the census enumeration, by block, are presented and discussed.

KEY WORDS: Census undercount; Dual-system estimation; Synthetic estimation; Post-enumeration survey.

## 1. INTRODUCTION

Since the first U.S. Census in 1790, problems have existed in finding and counting every person who should be counted. Advances in demographics and statistics have permitted census coverage estimates to be produced, beginning with the 1950 census. Coverage estimates have been used to evaluate census shortfalls and determine areas of needed improvements for succeeding censuses. The census coverage estimates have shown a steady improvement in census taking since the 1950 estimates were produced. One series of estimates shows the U.S. level undercount was 4.4% for 1950, 3.3% for 1960, 2.8% for 1970 and 1% for 1980. Despite this continuing reduction in the percent undercount, estimates remain higher for certain groups in the U.S. For example, the black undercount has remained about 5 percent above the national average.

Results also indicate high undercounts are measured for other ethnic groups-especially the Hispanic population. Central cities have higher undercounts as do rural areas. Males have higher undercounts than females. The age group 20 to 45 also has a high undercount.

The methods used since 1950 to measure the undercount in the U.S. are a post-enumeration survey (PES) and demographic analysis. The Census Bureau has announced that these will be the major tools to estimate the undercount for the 1990 census. A PES uses an independent sample of persons that are matched to the census to estimate the total population. Marks (1978)

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and U.S. Census Bureau (1979) describe previous work on using a PES to measure census coverage. Demographic analysis uses birth, death and other administrative records to estimate the total population in the U.S. Fay *et al.* (1988) describe the 1980 undercount estimates from demographic analysis and the Post-Enumeration Program (PEP).

In 1980, increased scrutiny of census numbers resulted in a number of court suits arguing for an adjustment of the 1980 census counts. Some of the issues that led to the court suits include: the existence of the differential undercount between blacks and nonblacks; the introduction of revenue sharing in the 1970's which tied monies directly to population counts; and declining populations in some cities and states which have traditionally had higher undercounts. The U.S. Census Bureau argued against adjustment of the 1980 census for the measured undercount on the basis that the measurement was error prone and an adjustment would not improve the unadjusted census counts.

The Census Bureau did embark on a research program after 1980 to evaluate alternate methods and ways to improve the undercount measurement process (Mulry *et al.* 1981 and Hogan 1984). Hogan (1984) proposed a series of tests to improve the undercount measurements in conjunction with the test censuses. These started with a PES in Tampa, Florida in 1985 to test and evaluate computer matching. This test verified the feasibility of computer matching (Jaro and Childers 1986). Test censuses and PES's were also conducted in 1986 in Los Angeles and Mississippi. A PES was conducted in Los Angeles to test the timing and operational aspects of adjusting the census. In Mississippi, a PES was conducted to evaluate the PES operations in a rural test site (Anolik 1988).

A Pre-Enumeration Survey was also conducted in 1986 in Los Angeles to determine if further gains in timing could be obtained if some of the field work was conducted before the census rather than after the census enumeration as in a PES (Wolfgang 1987). A PES was conducted in 1987 in rural North Dakota for evaluation of the PES operations in rural areas, where a door-to-door enumeration is conducted rather than a mail-out census as in the other test sites. Finally, work is under way for the 1988 Census Dress Rehearsal. The Dress Rehearsal will be used to test all census operations before conducting the 1990 Decennial Census.

The focus of this paper is on the 1986 PES in Central Los Angeles County, called the Test of Adjustment Related Operations (TARO), conducted in conjunction with the test census. The test site comprised three major race/ethnic groups: Hispanic, about 75% of the total population; Asian, about 15%, and Other, mostly white, with about 10% of the total population. The results of the PES show an estimated undercount of 9%. For the major race/ethnic groups in the test site, the Hispanic, Asian, and Other undercounts are estimated at 9.8%, 7.3%, and 6.2%, respectively. This paper describes the methodology and operational aspects of estimating these undercounts.

Section 2 presents the methodology used in 1986 to measure the undercount and how to incorporate the undercount estimates into the census count to produce an adjusted census. Section 3 discusses the schedule of operations in carrying out TARO including field operations and matching. Section 4 presents a summary of the undercount estimates for the poststrata and undercount estimates at the block level. Section 5 summarizes the major findings and presents some conclusions.

## 2. METHODOLOGY

### 2.1 Overview of Samples Used in Estimation

To estimate the popluation, the PES used two samples, called the P (for Population) sample and the E (for Enumeration) sample. The P sample is used to measure census omissions. The E sample is used to measure census erroneous enumerations.

The P sample consists of a block sample with an an independent listing of housing units and personal interviews whereas E-sample data are the census enumerations (counts) from the same sample block. The P sample obtained data needed for matching and estimation including census day residence. A design decision was made that defined who is included in the P sample. The P sample was all persons living at the sampled address at the time of the PES interview. The alternate procedure would interview the residents on census day. We decided against the latter approach because all movers involve proxy respondents (interview is from nonhousehold members). For the approach chosen, movers were living at the sample address and can have completed interviews without resorting to a proxy respondent. However all residents on census day who moved outside the test site before the PES interview have zero probability of being captured in the P Sample. All P-sample persons who lived outside the test site on census day were considered out-of-scope.

After interviewing, all P-sample persons were matched to the census. A computer matching program was used with clerical review. A second design decision defined the extent of search for matching. The PES classified a P-sample person as matched if the person was counted in the census anywhere in the test site. An alternate procedure would define a more limited search area, such as the PES block and neighboring blocks. Then a P-sample person is called a match only if the corresponding census person is within this search area. As an aside, the 1990 PES procedure will use a limited search area for matching.

All unresolved cases from matching were sent to followup to obtain additional information for matching. The followup workload from the P sample was greatly reduced by asking all questions needed for matching at the time of the original interview. Therefore only incomplete personal characteristics, incomplete mover address, and uncertain match cases were sent to followup from the P sample. Nonmatched P-sample cases were considered resolved and not sent to followup. Many E-sample persons are matched to P-sample persons and are resolved without the need of another interview. All E-sample persons not resolved from the P-sample interview were sent out for a followup interview that is used to determine their enumeration status. Operational aspects are discussed in more detail in the following section. The types of census erroneous enumerations measured by the E sample included geocoding error, duplication, fabrication, persons born after census day, persons who died before census day and unmatchable cases. Geocoding error is defined as a census enumeration that exist outside the search area, the entire test site. Unmatchable cases are census enumeration without a name. Unmatchable cases cause an overestimate of the number of erroneous enumeration, but are treated in a similar manner as erroneous enumerations in the estimator.

### 2.2 Dual-System Estimation

In order to estimate the total population, a dual-system estimator is used which combines the information from the P and E samples. Wolter (1986) describes different dual-system estimators and their underlying assumptions. The dual-system estimator used in TARO is written

$$\text{DSE} = \frac{N_p(\text{CEN-SUB-EE})}{\text{M}}, \tag{1}$$

where $N_p$ = estimator of the total PES population, CEN = unadjusted census count, SUB = number of census whole-person substitutions, EE = estimator of the number of erroneous enumeration and unmatchable persons included in the census, derived from the E sample, M = estimator of the number of persons in both the census and the PES populations. Census whole-person substitutions are defined as any person included in the census with fewer

**Table 1**
Dual-System Classification

| | | P-Sample Target Population | | |
|---|---|---|---|---|
| | | In | Out | Total |
| Census | In | $N_{11}$ | $N_{12}$ | $N_{1+}$ |
| Enumeration | Out | $N_{21}$ | $N_{22}$ | $N_{2+}$ |
| | Total | $N_{+1}$ | $N_{+2}$ | $N_{++}$ |

than two demographic characteristic. In order to better understand and explain some of the unique features of the dual-system estimator, Table 1 shows the classification of each person in the population.

The population quantities in Table 1 are estimated by components of the dual-system estimators: $\hat{N}_{11} = M$, $\hat{N}_{+1} = N_p$, $\hat{N}_{1+}$ = CEN-SUB-EE. The value of $N_{22}$ is unobservable by definition but is estimated by assuming independence between the census enumeration and the P sample of the PES. The estimate of $N_{22}$ is given by

$$\hat{N}_{22} = \hat{N}_{12}\hat{N}_{21}/\hat{N}_{11}. \tag{2}$$

By using the estimators defined above, the estimate of the total population is given by $\hat{N}_{++}$ = DSE.

Because of problems in matching census data, special handling is needed to prevent an overestimate of the population. The dual-system estimator assumes every person is uniquely assigned to one cell in Table 1. So instead of just using the census count, the estimate of erroneous enumerations is subtracted from the census count to give an estimate of the number of unique persons counted in the census. Additionally, the dual-system estimator assumes each person can be called a match or a nonmatch. Census enumerations with insufficient information for matching (e.g., no name or fewer than two demographic characteristics) cannot be called matches or nonmatches with certainty. Therefore, unmatchable persons are also subtracted from the census count. All corresponding P-sample persons are called nonmatches and assigned to the $N_{21}$ cell.

### 2.3 Sample Design

The sample design was a stratified sample with the sampling unit being a block. Two types of data were used to stratify the test site — a count of housing units by block obtained from the 1986 census address file and a mapping of 1980 census race data into the 1986 census geographic units. This mapping could only be made at the census tract level which equals one to six blocks. Therefore, the assignment of the racial grouping was done at the census tract level. All blocks within the census tract were assigned to the same racial category, and thus were in the same stratum.

The test site was stratified into six sampling strata, described in Table 2.

All blocks with special places (mostly group quarter population) were put into a separate sampling stratum. These blocks were considered out-of-scope and were not sampled. Small blocks were placed in a separate stratum to reduce the sampling variance. All blocks in census tracts with at least 18% Asian defined the Asian strata. All non-Asian blocks in census tracts with at least 40% Hispanic defined the three Hispanic strata. All remaining blocks that were not in the above strata defined the Other strata.

**Table 2**
Sampling Strata and Allocation of Sampled Blocks

| Sampling Strata | Number of Blocks Sampled |
|---|---|
| 1. Hispanic Blocks with large multiunits | 8 |
| 2. Hispanic Blocks with small multiunits | 49 |
| 3. Hispanic Blocks with single units | 39 |
| 4. Asian Blocks | 35 |
| 5. Other Blocks | 38 |
| 6. Blocks with two or fewer housing units | 21 |

The 1986 housing count data also contained information on single unit and multiunit structures. These data were used to split the Hispanic strata into single unit, small multiunit, and large multiunits. The Hispanic large multiunits stratum was defined as the Hispanic blocks with 50% or more of the housing units in structures with 10 or more addresses. The Hispanic single unit stratum was defined as the Hispanic block with more than 50% of the housing units in single units. The Hispanic small multiunits stratum was defined as the remainder of the Hispanic blocks.

Within each of the sampling strata, an equal probability systematic sample of blocks was chosen. The sample consisted of 190 blocks containing about 6000 housing units. Table 2 contains the breakdown of the sampled blocks by the sampling strata. Large blocks with 70 or more housing units were subsampled to reduce the interviewing workload. The subsampling consisted of splitting the block into clusters of 35 to 50 housing units, using address ranges or block faces. One cluster was randomly selected for P-sample interviewing. The E sample was defined as all persons the census counted in the same cluster.

### 2.4 Poststratification

The dual-system estimator is biased and the bias can be large if the undercount rates are significantly different for subgroups of the population (Wolter 1986). To control this bias, the test site was partitioned into groups (poststrata) felt to have the similar undercount rates. Dual-system estimates were then calculated within each poststratum.

The poststrata were chosen by examining the test site composition and from analysis of the 1980 PES data. The most important discriminating variable of the undercount was race. Three race-ethnic groups were used: Hispanic, Asian and Other. A separate poststratum for blacks was not possible since few blacks lived in the test site. Minority renter was an important explanatory variable in our previous research (Isaki *et al.* 1987). Therefore, tenure was also used in constructing the poststrata. Hispanics living in a block with fewer than 50% of the population being Hispanic (called Non-Hispanic blocks) were thought to have a different undercount rate from other Hispanics and was assigned to a separate poststratum. Table 3 shows the seven race-tenure groups which are crossed by age (0-14, 15-29, 30-44, 45-64, 65+) and sex to give the 70 poststrata used in estimation.

Table 3 also shows the sample sizes for the P sample and for the E sample. The lower sample size for the P sample than the E sample is partly explained by inmovers in the P sample which are treated as being out-of-scope.

**Table 3**
Race-Tenure Categories Used in Poststratification, Including Sample Sizes

| Race-Tenure Categories | P Sample | E Sample |
|---|---|---|
| Hispanic Renters in Hispanic Blocks | 8,182 | 8,739 |
| Hispanic Owners in Hispanic Blocks | 5,688 | 5,867 |
| Hispanics in Non-Hispanic Blocks | 896 | 1,005 |
| Asian Renters | 666 | 911 |
| Asian Owners | 1,144 | 1,230 |
| Other Renters | 1,135 | 1,316 |
| Other Owners | 1,841 | 1,908 |
| Total | 19,552 | 20,976 |

## 2.5 Handling Missing Data

To compute the dual-system estimates, a complete data file is needed. The 1986 test contained missing data, as is true for any sample survey. Schenker (1988) presents a description of the methods used to handle missing data, including some effects of different assumptions about missing data on the dual-system estimates. For completeness, we give a brief desciption of the methods.

Missing data occurred for person and household characteristics, the match status (matched/nonmatched) for the P-sample persons, and enumeration status (correct/erroneous) for the E-sample persons. For P-sample noninterviews, a weighting adjustment was used. Missing characteristics were imputed using a "hot-deck" procedure. For match status, a logistic regression model was used to estimate the probability of being matched. Rather than assign a definite match or nonmatch status to each unresolved case, the estimated probabilities were used in the dual-system estimates. An analogous procedure was used for missing E-sample enumeration statuses.

## 2.6 Small Area Estimation

To make an adjustment additive at all levels of aggregation for users, the estimates of the undercount are carried down to the block level (the smallest geographical unit). But before carrying the undercount estimates to the block level, a regression model is used to "smooth" the effects of sampling error. Adjustment factors are used as the dependent variable in the regression model. An adjustment factor is defined as the dual-system estimator divided by the census count:

$$Y = \text{DSE/CEN}, \tag{3}$$

where CEN and DSE were defined previously.

The regression model is written as

$$Y_i = B_o + B_1 X_{i1} + \ldots + B_p X_{ip} + S_i + E_i, \tag{4}$$

where $Y_i$ = adjustment factor for the $i$-th poststratum ($i = 1, \ldots, 70$), $X_{ij}$ = independent variable ($j = 1, \ldots, p$), $B_j$ = regression coefficient to be estimated, $S_i$ = sampling error of the adjustment factor, $E_i$ = model error, and the $S_i$ and $E_i$ are independent and normally distributed with mean 0 and variances equal to $\sigma_i^2$ and $\epsilon^2$ respectively. The $\epsilon^2$ and $B_j$'s are estimated using maximum likelihood methods (Ericksen and Kadane 1985). The $\sigma_i^2$ are estimated directly from the sample. The sample-based adjustment factor and the model-based adjustment factor are averaged together to form the predicted adjustment factor

$$AF_i = \left(Y_i/\sigma_i^2 + \sum_j X_{ij}\hat{B}_j/\epsilon^2\right)\left(\sigma_i^{-2} + \epsilon^{-2}\right)^{-1}, \tag{5}$$

which is used to adjust the census block data. The variance of $AF_i$ can be obtained from the results in Freedman and Navidi (1986).

Synthetic estimation was used to carry down the adjustment from each poststratum to the census block. The synthetic estimator is written as

$$ADJ_{iJ} = AF_i \times CEN_{ij}, \tag{6}$$

where $i$ and $j$ denote the poststratum and block respectively and $ADJ$ is the adjusted population at the block level.

The adjusted block population, $ADJ_{ij}$, is usually a noninteger number. The census counts whole persons. In order to incorporate the adjustment into the census, the noninteger values must be transformed into integers. Integerization (or controlled rounding) rounds all values to the integer part of the number or to the integer part of the number plus one (Causey *et al.* 1985).

After integerization of the adjusted block estimates, counts were produced for the number of persons by age-race-sex to be added to or substracted from each block. In the case of undercounts, a census enumeration having the same range of characteristics as the estimated missed person was randomly selected from within the block and copied into a new census record. A nonhousehold category was used to add persons to the census so that household relationships and creation of new households were not needed. Zaslavasky (1988) describes an alternate procedure, using weighting, for adding persons and households to census blocks. In the case of overcounts, census persons with the required characteristics would be flagged and would not be counted in the adjusted census tabulations.

## 3. OPERATIONS AND TIMING

The major focus of this test census was to study the timing and operational aspects of adjusting the census. Previous PES's at the Census Bureau have taken about two years or longer to complete. For example, the 1980 PES produced undercount estimates in the fall of 1981 and a final set of estimates in early 1982.

Table 4 presents the major census and PES operations and their start and end dates. Gaps exist in Table 4 because all census and PES operations are not listed. Some PES operations have overlapping time schedules since these operations were occurring at the same time. PES activities started after all major census field activities were completed. This helps ensure independence between the census and the PES by having the field staffs working at different times.

**Table 4**
1986 TARO Operational Schedule

| Operation | Start | End |
|---|---|---|
| Census Day | March 16 | March 16 |
| Nonresponse Followup | April 09 | May 08 |
| Key Census Names | May 23 | June 10 |
| Census File for Matching | Aug. 08 | Aug. 15 |
| PES Address Listing | June 17 | June 21 |
| PES Subsampling | June 25 | July 01 |
| PES Interviewing | June 25 | Aug. 08 |
| Key PES form | July 21 | Aug. 19 |
| Computer Match | Aug. 28 | Sept. 09 |
| Extended Computer Match | Sept. 09 | Oct. 03 |
| Clerical Match | Sept. 15 | Oct. 31 |
| Field Followup | Sept. 23 | Nov. 06 |
| Followup Matching | Sept. 29 | Nov. 06 |
| Key Match Results | Oct. 21 | Nov. 10 |
| Prepare P- and E- sample files | Nov. 11 | Jan. 02 |
| Imputations | Jan. 05 | Jan. 11 |
| Final Census file | - | Jan. 05 |
| Estimate Poststrata | Jan. 12 | Feb. 11 |
| Small Area Estimates | Feb. 12 | Feb. 22 |

The census was conducted by mailing a questionnaire to every known housing unit and asking a household member to complete the form on Census Day (March 16). Each household that failed to mail back its questionnaire was completed in person by an enumerator. This is called nonresponse followup. Completed forms were sent to the processing office for entering the data, which included for this test all census names, into the computer.

The first step of the PES produced an independent listing of all addresses in the sample blocks. The listings were compared to an administrative list to ensure accuracy and completeness. This quality control check showed that 127 (67%) blocks had no change to the address listing. The remaining 63 (33%) blocks had changes made from the quality control check and were relisted. The relisting added addresses to 37 blocks, corrected addresses in 39 blocks, and deleted addresses in 9 blocks. (Since multiple changes were made for some blocks, the above numbers do not add up to the total number of relisted blocks.) The changes in the address listings from the quality control check showed only minor corrections. After passing the quality control check, all blocks of 70 or more housing units were subsampled using block faces or address ranges.

The PES interview was conducted by personal visits. Questions were asked of all current residents to obtain their demographic characteristics. Special questions asked about residence on Census Day, mailing address, alternate addresses such as college residence, and other persons who may have lived at this residence on Census Day. A quality control check of the PES questionnaire verified the roster of names. For the sample of forms checked, 96% passed the quality control operation. The 4% that failed the quality control check were reinterviewed and corrected.

The final outcome of the interviewing showed that 5,714 (93.2%) of the housing units had a completed interview with a household member. Another 193 (3.1%) housing units were vacant and 189 (3.1%) housing units had a completed interview with a non-household member (e.g. neighbor). Only 32 (0.5%) housing units were coded as noninterviews. The extremely low noninterview rate is attributable to the 5 week interviewing period.

As the PES questionnaires were completed they were prepared for computer matching to the census file. The computer matching was split into two parts: first, matching the PES data with the E-sample data and second, called extended computer matching, matching all P-sample cases that did not match in the first part of the computer matching to the remaining census data. The extended computer match was used to match movers between Census Day and the time of the PES interview and geographical coding errors, i.e., where the housing unit is assigned to the wrong block. The first part of the computer matching assigned a match to 14,700 (73.5%) of the P-sample cases and assigned a possible match to another 2,550 (12.0%). The extended computer matching assigned a match to another 130 persons (0.7%) and assigned a possible match to another 570 persons (2.9%). Because the extended computer matching assigned a match status to only a small percentage of P-sample cases, we concluded that the geographical coding in Los Angeles had few errors.

Clerical matching reviewed the results of the computer matching. Clerical matching also identified the cases with insufficient data for matching (for which imputation is necessary). Clerical matching prepared followup forms for unresolved P-sample and E-sample cases.

Field followup consisted of 1,551 housing units with 1,511 (97.4%) being recorded as completed interviews. The field followup was followed by final matching. The final P-sample results show that 17,018 (85.2%) persons were matched to a census persons and 2,373 (11.9%) persons were not matched. Another 426 (2.1%) persons were considered out-of-scope (mostly persons who lived outside the test site on Census Day) and 161 (0.8%) persons were unresolved (and later had match status imputed). The final E-sample results show that 19,637 (93.6%) persons were correctly enumerated and 360 (1.7%) were erroneously enumerated in the census. Another 976 (4.7%) persons were unresolved and had an enumeration status imputed.

All missing data after final matching including match status for the P sample and enumeration status for the E sample were imputed. The results were used to create the dual-system estimates. The estimates were smoothed and carried down to the block level to create an adjusted census file. The improvements in timing to produce the undercount estimates were mainly due to the matching activities. The computer and clerical matching for TARO took about 3 months, while the 1980 PEP matching activities took over one year to complete. Additional time savings were due to improved planning of operations and better access of census materials.

## 4. ESTIMATES

### 4.1 Poststrata Estimates

This section presents the undercount estimates for various aggregations of the poststrata. Table 5 presents the percent undercount 100(1-CEN/DSE), percent nonmatched 100(1-M/$N_p$), percent erroneously enumerated 100(EE/CEN), and percent substituted 100(SUB/CEN).

A feature of the dual-system estimator is that the estimates summed over several categories does not equal the direct estimate of the summed categories. To keep the estimates reported in Table 5 consistent, all estimates are summed over the other relevant categories.

Examining Table 5 for percent undercount by the race-tenure groups, one concludes: tenure is a good stratification variable with higher undercount estimates for renters than for owners; race/ethnicity also differentiates the undercount with higher undercount estimates for Hispanics than for Asians, which in turn are higher than for Others. Percent erroneously enumerated is higher for renters than for owners, but almost no differences between the race/ethnicity groups. Percent substituted is higher for Hispanic and Other renters than for Hispanic and Other owners. Asian owners had a higher percent substituted than Asian renters, the reverse from the two other race-ethnicity groups.

**Table 5**

Percent Undercount and the Components of the Dual-System Estimates for the Poststrata

| Post-Strata | Percent Undercount[a] | Percent Nonmatched of the P-Sample | Percent Erroneously Enumerated of the E-sample[b] | Percent Substituted of the Census |
|---|---|---|---|---|
| Hispanic Renters in Hispanic Blocks | 13.7 | 17.1 | 2.6 | 1.7 |
| Hispanic Owners in Hispanic Blocks | 5.5 | 8.1 | 1.2 | 1.5 |
| Hispanics in Non-Hispanic Blocks | 7.5 | 9.7 | 1.4 | 1.3 |
| Asian Renters | 11.1 | 13.4 | 2.1 | 1.2 |
| Asian Owners | 4.6 | 6.8 | 1.2 | 1.5 |
| Other Renters | 9.9 | 12.9 | 2.4 | 1.7 |
| Other Owners | 3.8 | 5.8 | 1.3 | 0.9 |
| 0-14 | 8.8 | 11.9 | 2.2 | 1.6 |
| 15-29 | 13.6 | 16.2 | 2.1 | 1.6 |
| 30-44 | 8.6 | 10.8 | 1.4 | 1.4 |
| 45-64 | 4.5 | 6.6 | 1.3 | 1.4 |
| 65+ | 3.3 | 5.9 | 1.7 | 1.3 |
| Male | 9.7 | 12.1 | 1.7 | 1.5 |
| Female | 8.3 | 10.8 | 1.9 | 1.5 |
| Total | 9.0 | 11.4 | 1.8 | 1.5 |

[a] All estimates are summed over all other catetgories.
[b] Erroneously enumerated includes unmatchable nonsubstituted.

Examining Table 5 for percent undercount by age and sex one observes that the age group 15-29 had the highest undercount and males have a higher undercount than females. The age groups 0-14 and 30-44 have similar undercount estimates, slightly below average for the test site. The age groups 45-64 and 65+ also have similar undercount estimates, well below the other age groups. These results are fairly consistent in distribution with previous undercount results.

Percent erroneously enumerated is highest for the two youngest age group 0- 14 and 15-29. The age groups 30-44 and 45-64 have similar low estimates of percent erroneous enumerated. Surprisingly the percent erroneously enumerated is in the middle for the age group 65+. Small differences are observed in percent erroneous enumeration for the sex groups. Only small differences are observed for percent substituted for the age groups or the sex groups.

### 4.2 Small Area Estimates

Before applying the adjustment at the block level, as mentioned earlier, a regression model was fitted to "smooth" the data and reduce the effects of sampling variability. The regression

model was fit to the 70 adjustment factors as defined by the poststrata. The regression modelling is used to find a common pattern of undercounting in the data. Then the sample-estimated adjustment factors are shrunk toward this common pattern. This is similar in spirit to the James-Stein estimator and empirical Bayes estimators. The independent variables that were available to use in the model were indicator variables for the race-tenure groups, for the age groups, and for the sex groups. No interaction terms were allowed to enter the model. The model that fit the data and had significant coefficients (under an unweighted regression model) was the following:

$$\hat{Y} = 1.038 + .090(HR) + .044(AR) + .013(OR) + .058(A15\text{-}29) - .009(A45\text{-}64)$$

where $\hat{Y}$ = model-based adjustment factor

HR = 1 if Hispanic Renter in Hispanic Blocks
= 0 otherwise

AR = 1 if Asian Renter in all Blocks
= 0 otherwise

OR = 1 if Other Renter in all Blocks
= 0 otherwise

A15-29 = 1 if age group 15-29
= 0 otherwise

A45-64 = 1 if age group 45-64
= 0 otherwise.

The regression model shows the larger undercount estimates for all renters over owners. Also the age group 15-29 has much higher undercount estimates than other age groups. The age group 45-64 has lower undercount estimates than the other age groups. The variable sex was statistically insignificant and was not included in the model. Two adjustment factors, Hispanics in Non-Hispanic blocks male 65 + and Asian renters male 65 + , had a zero estimated variance and were not included in the model. The predicted adjustment factor was defined as the sample-estimated adjustment factor for these two adjustment factors.

Table 6 contains the sample-estimated and predicted adjustment factors for the 70 poststrata. In general, the predicted adjustment factors lowers the highest estimated adjustment factors and raises the lowest estimated adjustment factors. The predicted adjustment factors have less variability than the sample-estimated adjustment factors. The most notable example of the effects of the regression model is for Asian renters female age 65 + . The predicted adjustment factor is 1.087 rather than the sample estimated adjustment factor of 1.212. This predicted adjustment factor is closer to the expectations of a lower undercount for the age group 65 + than for the other age groups.

The predicted adjustment factors were multiplied by the census counts for the 2,405 blocks in the test site. The adjusted census counts were rounded to form integer values. Although three predicted adjustment factors were less than one (an estimated overcount), the integerization process did not produce any adjusted overcounts.

The adjustment process added 32,843 people to the census, a 8.2% undercount rate. If the sample-estimated adjustment factors were used, then 36,454 people would have been added to the census, a 9.0% undercount rate. The process of smoothing lowered the undercount estimate by almost 10%. This occurred because the largest undercount estimates were lowered by the smoothing and these same groups had the largest population counts.

**Table 6**

Results of Smoothing TARO Adjustment Factors

| Poststrata | Sex/Age | Estimated | | Predicted | |
|---|---|---|---|---|---|
| | | Adj. Factor *Y* | Std. Error | Adj. Factor *AF* | Std. Error |
| HR in HB | M 0-14 | 1.131 | 0.020 | 1.130 | 0.016 |
| HR in HB | M 15-29 | 1.247 | 0.030 | 1.211 | 0.021 |
| HR in HB | M 30-44 | 1.165 | 0.029 | 1.144 | 0.020 |
| HR in HB | M 45-64 | 1.099 | 0.043 | 1.114 | 0.024 |
| HR in HB | M 65+ | 1.055 | 0.044 | 1.110 | 0.023 |
| HR in HB | F 0-14 | 1.124 | 0.023 | 1.126 | 0.018 |
| HR in HB | F 15-29 | 1.234 | 0.032 | 1.203 | 0.022 |
| HR in HB | F 30-44 | 1.084 | 0.017 | 1.098 | 0.015 |
| HR in HB | F 45-64 | 1.125 | 0.040 | 1.121 | 0.024 |
| HR in HB | F 65+ | 1.099 | 0.045 | 1.122 | 0.024 |
| HO in HB | M 0-14 | 1.056 | 0.018 | 1.050 | 0.015 |
| HO in HB | M 15-29 | 1.078 | 0.018 | 1.084 | 0.015 |
| HO in HB | M 30-44 | 1.087 | 0.016 | 1.072 | 0.014 |
| HO in HB | M 45-64 | 1.031 | 0.012 | 1.031 | 0.011 |
| HO in HB | M 65+ | 1.073 | 0.028 | 1.054 | 0.019 |
| HO in HB | F 0-14 | 1.059 | 0.020 | 1.051 | 0.016 |
| HO in HB | F 15-29 | 1.088 | 0.016 | 1.090 | 0.014 |
| HO in HB | F 30-44 | 1.033 | 0.012 | 1.034 | 0.011 |
| HO in HB | F 45-64 | 1.020 | 0.012 | 1.022 | 0.011 |
| HO in HB | F 65+ | 1.033 | 0.019 | 1.035 | 0.015 |
| H in H'B | M 0-14 | 1.105 | 0.052 | 1.051 | 0.023 |
| H in H'B | M 15-29 | 1.154 | 0.054 | 1.106 | 0.025 |
| H in H'B | M 30-44 | 1.131 | 0.065 | 1.050 | 0.024 |
| H in H'B | M 45-64 | 1.063 | 0.050 | 1.036 | 0.023 |
| H in H'B | M 65+ | 0.991 | 0.000 | 0.991 | 0.000 |
| H in H'B | F 0-14 | 1.137 | 0.047 | 1.059 | 0.023 |
| H in H'B | F 15-29 | 1.033 | 0.022 | 1.060 | 0.017 |
| H in H'B | F 30-44 | 1.079 | 0.037 | 1.051 | 0.021 |
| H in H'B | F 45-64 | 1.033 | 0.028 | 1.031 | 0.019 |
| H in H'B | F 65+ | 0.947 | 0.040 | 1.013 | 0.022 |
| AR in all B | M 0-14 | 1.059 | 0.041 | 1.076 | 0.026 |
| AR in all B | M 15-29 | 1.127 | 0.044 | 1.137 | 0.028 |
| AR in all B | M 30-44 | 1.195 | 0.077 | 1.093 | 0.031 |
| AR in all B | M 45-64 | 1.004 | 0.057 | 1.063 | 0.030 |
| AR in all B | M 65+ | 0.982 | 0.000 | 0.982 | 0.000 |
| AR in all B | F 0-14 | 1.067 | 0.047 | 1.079 | 0.028 |
| AR in all B | F 15-29 | 1.215 | 0.055 | 1.153 | 0.029 |
| AR in all B | F 30-44 | 1.173 | 0.105 | 1.087 | 0.032 |
| AR in all B | F 45-64 | 1.012 | 0.061 | 1.065 | 0.030 |
| AR in all B | F 65+ | 1.212 | 0.127 | 1.087 | 0.032 |

**Table 6**

Results of Smoothing TARO Adjustment Factors - Concluded

| Poststrata | Sex/Age | Estimated | | Predicted | |
|---|---|---|---|---|---|
| | | Adj. Factor $Y$ | Std. Error | Adj. Factor $AF$ | Std. Error |
| AO in all B | M 0-14 | 1.045 | 0.030 | 1.041 | 0.019 |
| AO in all B | M 15-29 | 1.059 | 0.038 | 1.085 | 0.022 |
| AO in all B | M 30-44 | 1.091 | 0.040 | 1.053 | 0.022 |
| AO in all B | M 45-64 | 1.035 | 0.020 | 1.033 | 0.016 |
| AO in all B | M 65+ | 1.031 | 0.051 | 1.037 | 0.023 |
| AO in all B | F 0-14 | 1.040 | 0.041 | 1.039 | 0.022 |
| AO in all B | F 15-29 | 1.052 | 0.046 | 1.086 | 0.024 |
| AO in all B | F 30-44 | 1.035 | 0.036 | 1.037 | 0.021 |
| AO in all B | F 45-64 | 1.038 | 0.019 | 1.035 | 0.015 |
| AO in all B | F 65+ | 1.051 | 0.045 | 1.041 | 0.022 |
| O'R in all B | M 0-14 | 1.037 | 0.059 | 1.049 | 0.027 |
| O'R in all B | M 15-29 | 1.252 | 0.114 | 1.115 | 0.031 |
| O'R in all B | M 30-44 | 1.144 | 0.066 | 1.062 | 0.028 |
| O'R in all B | M 45-64 | 1.055 | 0.031 | 1.047 | 0.022 |
| O'R in all B | M 65+ | 1.068 | 0.056 | 1.054 | 0.027 |
| O'R in all B | F 0-14 | 1.148 | 0.062 | 1.064 | 0.027 |
| O'R in all B | F 15-29 | 1.126 | 0.054 | 1.112 | 0.028 |
| O'R in all B | F 30-44 | 1.134 | 0.057 | 1.064 | 0.027 |
| O'R in all B | F 45-64 | 1.068 | 0.041 | 1.049 | 0.025 |
| O'R in all B | F 65+ | 0.948 | 0.021 | 0.992 | 0.018 |
| O'O in all B | M 0-14 | 1.044 | 0.037 | 1.040 | 0.021 |
| O'O in all B | M 15-29 | 1.148 | 0.064 | 1.103 | 0.025 |
| O'O in all B | M 30-44 | 1.006 | 0.048 | 1.032 | 0.023 |
| O'O in all B | M 45-64 | 1.036 | 0.017 | 1.034 | 0.014 |
| O'O in all B | M 65+ | 1.017 | 0.019 | 1.025 | 0.016 |
| O'O in all B | F 0-14 | 1.159 | 0.068 | 1.052 | 0.024 |
| O'O in all B | F 15-29 | 1.081 | 0.042 | 1.092 | 0.023 |
| O'O in all B | F 30-44 | 0.997 | 0.017 | 1.011 | 0.014 |
| O'O in all B | F 45-64 | 1.025 | 0.012 | 1.026 | 0.011 |
| O'O in all B | F 65+ | 0.997 | 0.012 | 1.004 | 0.011 |

Note: H: Hispanic, R: Renter, B: Block, M: Male, F: Female, O: Owner, O': Other, H': Non-Hispanic, A: Asian. (Example: HR in HB: Hispanic Renter in Hispanic Block)

To summarize the block level adjustments, figure 1 shows the number of persons added by the number of blocks and figure 2 shows the percent of persons added by the number of blocks. Almost 80% of the blocks added less than 20 persons. Only 2 blocks added more than 150 persons. Those 2 blocks were fairly large, containing about 2,000 people each. Over 80% of the blocks had undercount estimates ranging from 4% to 12%. Many of the small blocks added a small percent of persons because the estimates were rounded down making a large change in the percent. The blocks with largest percent added were largely Hispanic and renters which had the largest predicted adjustment factors.

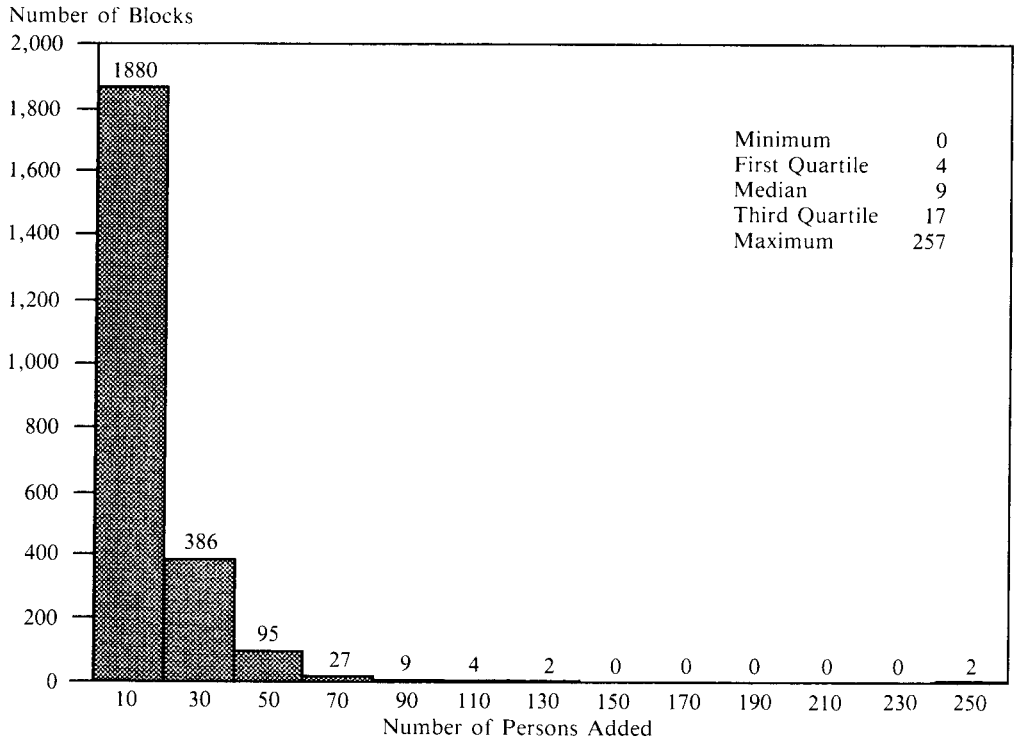


**Figure 1.** Number of Persons Added Per Block

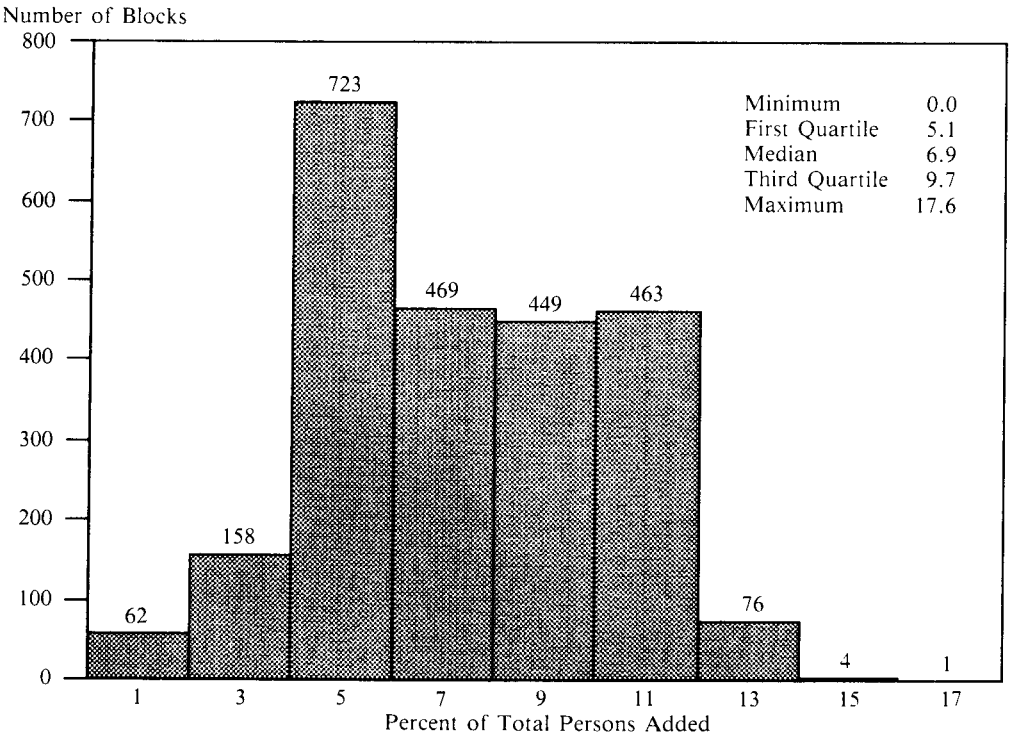


**Figure 2.** Percent of Total Persons Added Per Block

## 5. CONCLUSION

This paper discusses the methodology, operations, and the results of the Test of Adjustment Related Operations. TARO tested the operational and timing aspects of adjusting the census for estimated persons missed in the enumeration of the population.

The results from TARO demonstrate that undercount estimates can be produced in a timely manner. TARO was completed earlier than any previous PES.

TARO measured an undercount of 9% for the Central Los Angeles Count's test census. Separate dual-system estimates are presented for 70 race-tenure by age by sex categories. The dual-system estimates were smoothed by fitting a regression model to the estimates and then the resulting estimates were carried down to the block level. The use of block level undercount estimates allows aggregation to any level above the block.

Evaluation of the operations and assumption of the estimators are given in Schenker (1988) and Hogan and Wolter (1988). Together with this paper, they demonstrate a thorough evaluation of the census counts and the undercount estimates of the test census.

## ACKNOWLEDGEMENTS

I would like to thank the following people who contributed to this survey: Dan Childers, Howard Hogan, Cary Isaki, Matthew Jaro, Jan Jaworski, Charisse Jeffries, Robert O'Brien, Arona Pistiner, Nathaniel Schenker, Maria Urrutia, Debbie Wagner, and Kirk Wolter. I also would like to thank the referee for making comments that improved the presentation of this paper.

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