Appendix B. Errors and Source of the Estimates

SAMPLING AND NONSAMPLING ERRORS

The accuracy of the estimates contained in this report depends on (a) the sampling and nonsampling error, as measured by the error formulas in Tables 1a and 1b; (b) biases; and (c) other nonsampling errors not measured by the error formulas.

Below is an explanation of sampling and nonsampling error associated with the American Housing Survey (AHS).

Sampling Errors

Sampling error reflects how estimates from a sample vary from the actual value. (NOTE: By the term "actual value," we mean the value we would have gotten had all housing units been interviewed, under the same conditions, rather than only a sample.)

Suppose based on responses from the sample households we estimate there to be 1,300,000 housing units with a certain characteristic. Because we only interviewed a sample of all households there is a certain amount of "sampling error" in this estimate. Because of the sampling error, if we conclude the actual value is between 1,263,000 and 1,337,000 (a 50-percent confidence interval), there is only a 50 percent chance we'll be correct.

The formulas in tables 1a and 1b allow you to compute a range of error such that there is a known probability of being correct if you say the actual value is within the range. The error formulas are approximations to the errors. They indicate the order of magnitude of the errors rather than the actual errors for any specific characteristic. Use the starred formula to calculate standard errors for journey-to-work estimates only. For all other estimates, the error is the larger of the values calculated using the two formulas presented.To construct the range, add and subtract the error computed from the formulas to the publication estimate.

The letter "A" in the formula represents the publication estimate. Use the number as it appears in the publication (i.e., do not multiply it by 1,000).

The letter "W" is used to distinguish between journey-to-work estimates and all other estimates.

The letter "Z" determines the probability that the actual value is within the range you compute. The larger the value of Z, the larger the range, and the higher the odds the actual value will be in the range. The following values of Z are most commonly used:

Value of Z	Meaning
1.00	There is a 67-percent chance you will be correct if you say the actual value is in the range you compute.
1.60	There is a 90-percent chance you will be correct if you say the actual value is in the range you compute.
1.96	There is a 95-percent chance you will be correct if you say the actual value is in the range you compute.
2.58	There is a 99-percent chance you will be correct if you say the actual value is in the range you compute.

Note that if Z = 1.00, the formula computes the standard error. Ranges of 90 and 95 percent are commonly used. The range of error is also referred to as the confidence interval since there is a certain level of confidence that the actual value is within the interval.

The numbers in this book are printed in thousands (i.e., 21 printed in the book means 21,000 homes). The errors are also computed in thousands (i.e., do not multiply the number in the publication by 1,000 before computing the error).

For example, the book shows 1,300 elderly households of a certain type (meaning 1,300,000 households since the publication number is in thousands). To compute a 90-percent confidence interval, you would use the first formula in table 1a, and you would compute the error as follows:

$$Z \times \sqrt{(2.288 \times A) - (.000\,022 \times A^2)}$$

$$1.60 \times \sqrt{(2.288 \times 1{,}300) - (.000\,022 \times 1{,}300^2)}$$

$$1.60 \times \sqrt{2974.4 - 37.18} = 87$$

There is a 90-percent chance you will be correct if you conclude the actual value is 1,300 plus or minus 87, or in the range 1,213 to 1,387 (which means 1,213,000 to 1,387,000 since the numbers are in thousands).

If the estimate involves two characteristics from tables 1a and 1b, use the formula with the larger first number under the square root. For example, for mobile homes in the South, use the formula for the South since 2.435 is larger than 2.076.

Percents. You can also compute percents from the numbers in this book. The formula for computing the error of a percent is the following:

$$Z \times Y \times \sqrt{\frac{W \times P \times (100 - P)}{B}}$$

where

- Z defines the confidence the range will include the actual value,
- Y is the number from the last column of tables 1a and 1b (chosen based on the denominator),
- P is the percent you calculate, and
- B is the denominator of the percent,
- W is 2.644 for journey-to-work estimates,
- W is 2.288 otherwise.

For example, suppose there are 20,000 (actually 20,000,000) households in the Northeast and 8,000 (8,000,000), or 40 percent, are renters. To compute a 90-percent confidence interval, you would plug the following numbers into the above formula:

$$1.60 \times .935 \times \sqrt{\frac{2.288 \times 40 \times 60}{20{,}000}} = .8$$

Thus, if you say that the actual percentage of renters is between 39.2 and 40.8 percent of the households in the Northeast, there is a 90-percent chance you will be correct.

Differences. People often ask whether two numbers are actually different. If the range of error does not include zero, the numbers are different. As a general rule, if the confidence intervals do not overlap, they are different. To compute the range of error on the difference, use the following formula:

$$\sqrt{(\text{error on first number})^2 + (\text{error on second number})^2}$$

This formula is quite accurate for (a) the difference between estimates of the same item in two different areas or (b) the difference between separate and uncorrelated items in the same area. If there is a high positive correlation between the two items, the formula will overestimate the error. If there is a high negative correlation, the formula will underestimate the error. The following illustration shows how to compute the error of a difference.

Suppose there are 12,000 (12,000,000) owner-occupied units in the Northeast and 8,000 (8,000,000) owner-occupied units in the Midwest. The respective errors for a 90-percent confidence interval are 162 and 178. The error for a 90-percent confidence interval for the 4,000 (4,000,000) difference is the following:

$$\sqrt{(162)^2 + (178)^2} = 241$$

Thus, there is a 90-percent chance you will be correct if you say the actual difference between owner-occupied units in the Northeast and Midwest is between 3,759 and 4,241. Since the confidence interval does not include zero, we conclude these two estimates are, in fact, different.

Medians. The median is the value 50 percent of the way through the distribution. Thus, 50 percent of the total falls below and 50 percent falls above the median. You can construct a confidence interval around the median by computing the error on a 50-percent characteristic and translating that into an interval for the characteristic.

Use the following procedure to estimate the upper and lower limits of a confidence interval for a median:

1. Using the error formula for percents, above, compute the error of 50 percent. The total number of housing units from the distribution is the denominator in the formula. Subtract "not reported" or "do not know" categories from the total.
2. Calculate the confidence interval for 50 percent by adding and subtracting the error, from step 1, to 50 percent.
3. Translate the confidence interval for 50 percent to an interval for the characteristic. The lower and upper endpoints for the 50-percent confidence interval represent the percent of cases that fall below the respective endpoints of the interval for the characteristic. These values are found by linearly interpolating within the appropriate intervals of the distribution.

The probability you will be correct if you conclude that the actual median is within the interval depends on the value of Z in the error of percent formula. The following example shows how to compute a 90-percent confidence interval.

Suppose that the median number of rooms is 2.8. The number of housing units in the distribution of number of rooms is presented below.

Distribution of Number of Rooms

Number of rooms	Number of housing units (in thousands)
Total	56,000
1	900
2	20,000
3	22,000
4	8,000
5	4,100
Not reported	1,000

1. The error on a 50-percent characteristic based on 55,000 (55,000,000) housing units is calculated as follows:

$$1.60 \times 1.000 \times \sqrt{\frac{2.288 \times 50 \times 50}{55{,}000}} = .5$$

2. The 90-percent confidence interval for 50 percent is from 49.5 to 50.5.
3. Thus, 49.5 percent of the households will have less rooms than the lower endpoint of the 90-percent confidence interval. Thirty-eight percent of the households have two or less rooms and 78 percent have

three or less rooms. Thus, the value corresponding to 49.5 percent of the households is somewhere in between. The equation for linear interpolation is the following:

$$2.5 + (3.50 - 2.50)\frac{49.5 - 38.0}{40.0} = 2.79$$

where

2.5 is the upper endpoint of the interval of the distribution below the interval containing the value corresponding to the 49.5 percent from step 1.

3.5-2.5 is the length of the interval corresponding to the 49.5 percent. Note that the category "3 rooms" is represented by the interval 2.51 to 3.50.

49.5 is the lower endpoint of the 50-percent confidence interval.

38 is the percent of cases falling below the interval corresponding to 49.5 percent.

40 is the percent of cases within the interval corresponding to 49.5 percent.

Similarly, calculate the upper endpoint of the confidence interval according to the following:

$$2.5 + (3.50 - 2.50)\frac{50.5 - 38.0}{40.0} = 2.81$$

Thus, there is a 90-percent chance you will be correct if you conclude the actual median is between 2.79 and 2.81.

Ratios. For ratios of the form (100) (C/D), where C is not a subclass of D, the error of the ratio is approximately equal to the following:

$$\frac{C}{D}\sqrt{\left(\frac{\text{error of C}}{C}\right)^2 + \left(\frac{\text{error of D}}{D}\right)^2}$$

where

C = numerator of the ratio.
D = denominator of the ratio.

The following illustration shows how to compute the standard error of a ratio.

Suppose there are 12,000 (12,000,000) owner-occupied units in the Northeast and 8,000 (8,000,000) owner-occupied units in the Midwest. The ratio of owners in the Northeast to owners in the Midwest is 1.500. That is, there are one-and-a-half times as many owners in the Northeast as in the Midwest. The respective errors for a 90-percent confidence interval are 162 and 178 (use the formula for general characteristics for the Northeast and Midwest, respectively). The error for a 90-percent confidence interval for the ratio is the following:

$$\frac{12,000}{8,000}\sqrt{\left(\frac{162}{12,000}\right)^2 + \left(\frac{178}{8,000}\right)^2} = .039$$

Thus, there is a 90-percent chance you will be correct if you say the actual ratio of owners in the Northeast to owners in the Midwest is between 1.461 and 1.539.

Nonsampling Errors

We attribute nonsampling errors to many sources.

- The respondent may be unable or unwilling to provide the correct response.
- The interviewers may be unable to find the unit, or they may be unable to obtain information about all the cases.
- The interviewer may record the data incorrectly.
- Either the respondent or the interviewer may interpret the questions differently than intended.
- The collected data may be keyed incorrectly.
- The sample frames may be incomplete introducing some coverage error.
- Processing of the data introduces errors resulting from rounding or adjusting for missing values.

There are also other errors of collection, response, processing, coverage, and estimation of missing data. The following describe some sources of nonsampling errors and/or methods to measure these errors. We have included the impact on the AHS data where available. The most noteworthy of these are as follows:

- Response error, which we measure by reinterviews.
- Coverage error.
- Errors resulting from incomplete data, which includes nonresponse as well as coverage errors.
- Computer Assisted Telephone Interviewing (CATI), which also uses the reconciliation experiment to measure data quality.

Another source of error affecting estimates of year-to-year change is the switch from 1980- to 1990-based independent controls. This is explained in the section on weighting.

Response error and the reinterview program. We usually reinterview a subsample of units to check for interviewers making up data as well as other reasons. The 1991 AHS-N reinterview served two purposes: (a) to evaluate interviewers and (b) to check for missed persons.

To evaluate the interviewers, we checked to make sure they did the following during the original interview:

a. Visited the correct unit.

b. Obtained the correct "tenure" information.

c. Obtained the correct "occupancy status" information.

The results of this check are not available yet.

The coverage check found we missed people in about 0.5 percent of the households (16 households from the reinterview sample). We missed roughly 1.6 persons per household (27 persons from the 16 households). These numbers are not exact and only indicate the order of magnitude of this source of error.

In 1985, the reinterview program measured some of the nonsampling errors associated with the AHS estimates in addition to serving as an interviewer evaluation. We assumed the original interview and the reinterview were two independent readings. We used these two readings to measure the response error.

We measured the response error for the following groups of items: (a) units in structure and description of structure; (b) number and type of rooms; and (c) appliances, including the age and fuel used by the appliances.

Item	Level of inconsistency for occupied units
Number of living rooms	Moderate
Number of dining rooms	Moderate
Number of family rooms	Moderate
Number of "Other" types of rooms	Moderate
Age of refrigerator	—
Age of garbage disposal	—
Age of oven/cooking burner	—
Age of dishwasher	—
Age of clotheswasher	Moderate
Central air-conditioning fuel	High
Cookstove or range with oven	Moderate to High

Dashes in the table above represent items that did not have enough observations to compute reliable estimates or items that had low levels of inconsistency. Low levels of inconsistency indicate response error is insignificant relative to the standard errors in this report. Moderate levels indicate response error is significant compared to the standard errors. High levels indicate the response error is very significant compared to the standard errors.

Cross-tabulations involving items subject to high levels of inconsistency may also be distorted. They are less reliable than comparable cross-tabulations that do not involve these data. The reinterview programs only measured inconsistencies for a sample of the items on the AHS questionnaire. There may be other items with high levels of inconsistency.

We also conducted reinterview studies in AHS enumerations before 1985. These studies included the following items:

- Poor housing quality.
- Attitudes about the respondents' neighborhood.
- Certain housing costs.
- Journey-to-work.
- Mobility data.

The following table shows items having moderate or high levels of inconsistency. These questions were not included in reinterview studies after 1985. However, we did not change the wording of questions from previous enumerations enough to believe the level of inconsistent responses would change.

Item	Level of inconsistency
Open cracks or holes on inside of building	Moderate to High
Holes in floors	Moderate to High
Broken plaster or peeling paint on ceilings and walls	High
Mice or rats	Moderate
Working electric outlet in all rooms	High
Concealed wiring	High
Blown fuses/tripped circuit breakers	Moderate to High
Neighborhood conditions: street noise; roads in need of repair; crime; trash, litter, junk in streets or on properties; boarded up/ abandoned structures; nonresidential activities; odors, smoke, gas	Moderate to High
Satisfactory neighborhood services: police protection; hospitals/health clinics; public transportation; shopping; elementary schools	Moderate to High
Electricity cost	High
Gas cost	High
Oil, coal, kerosene, wood or other fuel cost	Moderate to High
Fire/hazard insurance	Moderate to High
Real estate taxes	Moderate to High
Cost of real estate taxes	Moderate to High
Cost of water supply and sewage disposal	High
Cost of garbage collection	Moderate to High
Gross income	High
Type of vacant	Moderate to High
Prefer to live in same area or somewhere else	Moderate

One explanation for the reinterview results is that respondents may lack precise information. Also, since the reinterview results come from a sample survey, there is sampling error associated with these estimates of nonsampling error.

Processing errors. Several types of errors are associated with the processing of the data. The first type of processing error is keying error. A quality assurance operation helps ensure less than 0.4 percent of the questionnaire data fields will be incorrect.

Another type of processing error is rounding error. We process the data using double precision to minimize the effect of rounding error. However, rounding error may still be significant for small percentages and medians when we derive these statistics from relatively large bases. Confidence intervals formed from the standard errors may be distorted.

Coverage errors. AHS misses approximately 25 percent of the new mobile homes (i.e., those built after January 1, 1980). We believe most of the difference is because of poor coverage of new mobile home parks in address Enumeration Districts (see section on Sample Design).

The coverage of old construction housing units is only as good as the coverage of the 1980 census. The third stage of the ratio estimation procedure attempts to correct for this deficiency.

Deficiencies also exist in the sample of building permits representing conventional (i.e., nonmobile home) new construction. Because of time constraints, we only sample permits issued more than 6 months before interviewing.

This is more of a problem for single-unit rather than multiunit structures. The time between issuance of a permit and completion of construction for multiunit structures is generally more than 6 months depending on the size of the structure.

New construction in special places, such as colleges, or military bases is not covered in either permit or nonpermit areas.

To identify whole-structure additions in address and area enumeration districts (ED's), we listed and then screened potential sample units to see if they were eligible. The quality of the listing operation to identify potential sample units will affect the coverage of whole-structure additions. The coverage of these structures also depends on the quality of responses to the screening questions. Its possible eligible units were omitted and ineligible units included because of incorrect answers to the screening questions.

We also believe a coverage deficiency exists for units that converted from nonresidential units at the time of the 1980 census to residential units. We do not know the magnitude of this deficiency.

The second and third stages of ratio estimation adjust these deficiencies for the total number of housing units only. Biases of subtotals still exist. The error associated with these units is included in the error resulting from incomplete data, below.

Errors resulting from incomplete data. There are three main errors associated with incomplete data: (a) noninterview error, (b) missing housing units error, and (c) item nonresponse error.

Noninterview error occurs because noninterviews are not adequately represented by interviewed units in the noninterview weighting adjustment. The extent to which interviews do not represent noninterviews determines the magnitude of the nonsampling error from these units.

Missing housing units error occurs because the weighting adjustment does not adequately account for these units. We miss these units because the frames from which we selected the AHS-N sample had deficiencies (see Coverage Errors).

Item nonresponse error occurs because certain items on the questionnaire are blank because the respondent is unwilling or unable to provide a response. The computer assigns, or "imputes" values for these items. We do not know how close the imputed values are to the actual values.

For some items, there is no imputation for item nonresponse. Totals and subcategories of these items will be underestimated. Also, if the nonresponses are distributed differently than responses, percent distributions will be distorted.

The errors in table 2 are an innovative way of presenting incompleteness errors as standard errors. They should be regarded as examples of errors caused by incompleteness rather than exact errors for any specific estimate.

Table 2 errors are based on total estimates of various geographic levels. These geographic levels were chosen to be homogeneous sociologically and thus represent other characteristics. Therefore, they act as a proxy for items of various sizes. Although no specific data items (e.g., tenure) were used, the results were generalized to apply to all items. Thus, these errors may overestimate or underestimate the error for other data items.

For more detail on the methodology and the results, see a paper titled, "How Response Error, Missing Data and Undercoverage Bias Survey Data," by P. Burke (HUD) and G. Shapiro (Abt Associates, Inc.), D. Kostanich (Census), K. Mansur (Census), and L. Cahoon (Census). You can get a copy of this paper from Donna Kostanich in the Demographic Statistical Methods Division, Bureau of the Census at 301-763-2655.

As the paper referenced above explains, the standard errors in table 2 represent the variability (standard deviation) of the bias resulting from incomplete data modeled from the AHS-Metropolitan data. These errors do not reflect reductions in error resulting from the AHS-N weighting process which attempts to adjust for these incomplete data. Thus, we believe the errors in table 2 are overestimates of the error for incomplete data.

Although these errors seem unbelievably large compared to the sampling errors, consider the following scenario. Assume the completeness rate for an item is 90 percent. That is, 90 percent of the sample cases contained good data for the item.

There are about 100,000,000 units in the United States. A 90-percent completeness rate would mean about 10,000,000 housing units would have to be accounted for through imputation or weighting adjustments (i.e., 10 percent of the cases did not have good data for the item). Table 2 shows the standard error of the bias range from 126,000 to 1,941,000. These errors are small considering we could have incorrectly accounted for up to 10,000,000 units.

Completeness rates. Table 3 in appendix B of the *American Housing Survey for the United States in 1991*, Series H150/91, shows the completeness rates for items from chapter 2 in the publication, which provides estimates for characteristics of occupied housing units. The rates indicate what percent of the publication estimates are based on actual responses. The rates for the individual categories of items (e.g., income) take the following sources of incomplete data into account:

- Item nonresponse (i.e., imputation).
- Household nonresponse (e.g., refusals).
- Incomplete coverage (see second and third stage of ratio estimation).

The rates in table 3 are sorted from the lowest rate to the highest for total occupied units. As an illustration, we have provided, in the table below, completeness rates for three characteristics that are provided in this supplement. These characteristics have the lowest completeness rates of the characteristics provided in this supplement. Not all of the characteristics in table 3 are included in this supplement. Refer to the Series H150 publication for 1991 for the completeness rates of all other characteristics of occupied housing units except those pertaining to journey to work.

Completeness Rates for Selected Characteristics

Subgroup	Characteristic		
	Monthly housing costs as a percent of income	Household income	Selected amenities
Total occupied units	72	76	82
Owner	72	76	84
Renter	72	77	78
New construction	64	67	73
Mobile homes	72	76	80
Severe physical problems	69	74	78
Moderate physical problems	72	78	80
Black	63	68	72
Hispanic	75	79	77
Elderly	67	72	86
Moved in past year	71	76	77
Below poverty	65	71	79
In (P)MSA's—central cities	71	75	80
In (P)MSA's—suburbs	73	76	83
Outside (P)MSA's	73	78	84
Urban—total	72	76	82
Urban—outside (P)MSA's	73	78	85
Rural—total	73	77	84
Rural—suburbs	73	76	84
Rural—outside (P)MSA's	73	78	84
Rural—Farm	68	74	86
Northeast	72	76	81
Midwest	73	77	86
South	71	75	81
West	72	76	81

Possible effects of decentralized telephone interviewing on the data. We interviewed units for the 1991 AHS-National by decentralized telephone as much as possible. The exception was cases assigned to the Computer Assisted Telephone Interviewing (CATI) facility.

We conducted a large-scale decentralized telephone interviewing experiment for the 1983 AHS-National. Before 1983, all interviews were done by personal visits. The experiment provided detailed information about the effects of decentralized telephone interviewing on the data. We concluded that telephone interviewing had the following effect on the data. (a) It increased the item nonresponse rate for income items. This effect did not appear to cause changes in the published estimates. (b) It decreased reporting of problems with neighborhood quality, although this effect was minimal.

Possible effects of Computer Assisted Telephone Interviewing (CATI) on the data. There is strong evidence that differences exist in data collected by CATI and non-CATI. We do not know for sure, however, which method produces better data. Preliminary analysis of a CATI experiment conducted in 1987 indicated CATI had a substantial effect on some AHS-N characteristics. Another experiment conducted in 1989 confirmed the results of the 1987 experiment.

These findings affect all types of estimates and comparisons. In particular, change estimates across 1985, 1987, and 1989 are biased, and longitudinal analysis is adversely affected.

We made the following changes to the CATI interview for 1991 based on results from previous analyses:

a. We moved the heating equipment reconciliation from the end of the interview to right after the question. We also changed the response based on the reconciliation answer.

b. We added a probe and reconciliation to the question on the presence of a mortgage. We also changed the response based on the reconciliation answer.

c. We added a probe for lot size, units in structure, and the age of household appliances (e.g., refrigerator) if the respondent initially replied he/she did not know.

d. We improved the training for CATI interviewers, putting more emphasis on probing and dealing with "don't know" responses, and CATI supervisors.

Preliminary results indicate these changes helped reduce the number of differences between CATI and non-CATI estimates. Further analysis of the data is planned. (Note: The design of the CATI experiment is included in the sample design section of this appendix.)

Analysis of results. We used the same method of analysis for the 1987, 1989, and 1991 experiments. We weighted data from the CATI and non-CATI treatment panels separately using the AHS-N estimation procedure described in

the section on estimation. We produced estimates from the two treatments in data tables for characteristics provided in chapter 2 of the AHS-National publication. We used t-statistics to test differences between estimates from the CATI and non-CATI treatments.

The 1987 and 1989 analyses of the t-tests yielded similar results. The percents of significant differences observed at the 10-percent, 5-percent, and 1-percent significance levels were higher than what we expected by chance (e.g., we expected that 10 percent of the tests would yield significant results, by chance, when tested at the .10 significance level). For 1991, preliminary results show fewer significant differences than in 1987 and 1989, although the proportion is still higher than expected. It appears the changes introduced in 1991 had some affect on the CATI responses.

Proportion of Significant Tests

Year	Significance level (in percent)		
	.10	.05	.01
1987	11.1	6.2	1.9
1989	11.7	6.8	2.3
1991	10.2	5.9	1.7

For total occupied units, estimates for panels assigned to CATI compared with panels assigned to non-CATI treatment differed by about 6 to 40 percent. You can get detailed information on which specific characteristics are affected and the extent of the effect by writing to—

Demographic Statistical Methods Division
Bureau of the Census
Washington, DC 20233

The following table shows which groups had the most significant differences between CATI and non-CATI estimates for both 1987 and 1989.

Groups with Differences Between CATI and non-CATI Estimates

Group	1987	1989
Owner-occupied housing units	Y	Y
Urban housing units	Y	Y
Housing units with moderate physical problems	Y	Y
Total occupied housing units		Y
Housing units in the suburbs (in MSA's)		Y
Housing units that moved in past year		Y

Housing units with moderate physical problems had the highest number of significant differences.

For both 1987 and 1989, the analyses also revealed CATI had an effect on certain items within the groups. The following table contains those items and indicates whether CATI (C) or non-CATI (N) estimates were higher. If neither estimates were higher, the results were termed inconclusive (I).

Items Within Groups Showing Differences Between CATI and non-CATI Estimates

Item	1987	1989
Lot size	I	I
Water leakage	N	N
Income	I	I
Monthly housing costs as percent of income	N	N
Housing ownership shared by person not living in the unit	C	C
Utilities paid separately from rent	C	C
Owners with a mortgage	N	N
Routine maintenance costs	I	I
Heating equipment	I	I
Other (additional) heating fuels	N	N

Results of a reinterview study conducted in 1989 on 17 items (mainly mortgage and water leakage items) found weak evidence that CATI may produce more errors than non-CATI. CATI had a higher gross difference rate for 3 of the 17 items when tested at the 10-percent significance level. We cited significant differences between CATI and non-CATI estimates for two of the three items (water leakage and presence of a mortgage) previously.

Conclusions. The 1989 results confirmed the findings from the 1987 study. There is strong evidence there are differences in data collected using CATI and non-CATI methods. We do not know which method provides better data. However, we speculate that CATI income estimates are probably better than non-CATI, but that some other estimates are probably worse.

For income, CATI ensures all questions are asked. The computer will not allow the interviewer to skip any questions. For other items, we believe non-CATI estimates are more accurate because it is unlikely that people would overreport things like water leaks.

We used data from both CATI and non-CATI treatments to produce the data presented in the 1987 and 1989 publications. This will have the following impact on these data:

- The 1987 and 1989 published estimates for the groups and items mentioned previously are different than if we used maximum decentralized telephone interviewing for all units.
- There are probably other groups and items affected, but they either weren't detected or weren't included in these analyses. Cross-sectional comparisons for 1987 and 1989 involving these items are also affected.
- Estimates of 1985-1987 and 1985-1989 change for these items will be biased.
- The effect on estimates of 1987-1989 change for these items should be less than 1985-1987 or 1985-1989 change since we used CATI in 1987 and 1989. The extent to which we use CATI in the future will determine the impact on longitudinal analyses involving data from 1985 to 1991.

Reconciliation experiment. As part of the CATI, we conducted reconciliation studies in 1987, 1989, and 1991. If the responses for a particular year differed from the previous year, we asked the respondent to explain the difference. Our goal was to determine if there was a change since the previous year or if one of the responses was wrong. Results from the 1991 study are not available at this time.

1987 reconciliation study. The 1987 reconciliation study indicated respondents had difficulty reporting items such as the following: (a) presence of basement, (b) heating equipment, and (c) heating fuel.

The number of respondents who said their 1985 response was wrong was about the same as the number who said their 1987 response was wrong. Since we interviewed all households by personal visit in 1985, this indicates an effect caused by certain questions rather than the mode of interview.

1989 reconciliation study. We conducted a reconciliation study in 1989 with six of the nine questions from the 1987 study. The results were similar to the 1987 study. Results indicate problems reporting the presence of a basement and type of heating equipment. More than half of the respondents indicated that the 1987 response, rather than the 1989 response, was wrong.

SAMPLE DESIGN

This report is based on data collected from a sample of housing units interviewed between July and December 1991. The same basic sample of housing units is interviewed every 2 years until a new sample is selected. We update the sample adding newly constructed housing units and units discovered through coverage improvement efforts every enumeration.

For the 1991 AHS-National (AHS-N) survey, we selected approximately 56,700 sample housing units for interview. About 3,300 of these units were ineligible because (a) the unit no longer existed or (b) information relevant to the 1991 housing inventory could not be obtained for the unit.

We classified about 2,300 of the remaining units (both occupied and vacant housing units), as "noninterviews" because (a) no one was at home after repeated visits, (b) the respondent refused to be interviewed, or (c) the interviewer was unable to find the unit.

Sample Selection

We have interviewed the current sample of housing units since 1985. We selected the sample from the 1980 census in several steps. First, we divided the United States into areas made up of counties or groups of counties and independent cities, which we refer to as primary sampling units (PSU's). We selected a sample of these PSU's. Then we selected a sample of housing units within these PSU's.

Selection of sample areas. The sample for AHS is spread over 394 PSU's. These PSU's cover 878 counties and independent cities with coverage in all 50 States and the District of Columbia. If there was a sufficient number of housing units in a PSU, the PSU was known as a self-representing PSU and was in sample with certainty. The sample from the PSU represents only that PSU. There are 170 self-representing PSU's.

We grouped the remaining PSU's into strata and selected one PSU per stratum to represent all PSU's in the stratum. We refer to these PSU's as nonself-representing PSU's. The sample nonself-representing PSU's for AHS are a subsample of the Current Population Survey's (CPS) sample areas.

Selection of sample housing units. The AHS sample consists of the following types of housing units:

- Housing units selected from the 1980 census.
- New construction in permit-issuing areas.
- Housing units missed in the 1980 census.
- Other housing units added since the 1980 census.

Housing units selected from the 1980 census. We selected a sample of housing units from the 1980 decennial census files using an overall sampling rate of about 1 in 2,148. We determined the within-PSU sampling rate so the overall probability of selection for each sample housing unit was the same (e.g., if the probability of selecting a nonself-representing PSU was 1 in 10, then the within-PSU sampling rate would be 1 in 214.8).

We classified the areas within a PSU into two types based on (a) the completeness of the addresses in the areas that make up the PSU and (b) the presence of a system to monitor new construction through building permits.

The two types of areas were known as address enumeration districts (ED's) or area enumeration districts. We selected the sample of 1980 census units differently in the two types of areas.

In address ED's, most of the housing unit addresses were complete, and the construction of new housing units was monitored by building permits. We selected a sample of housing units from the list of units that received long-form questionnaires in the 1980 census.

We also used the census files to select a sample of living quarters in address ED's that did not meet the definition of a housing unit (e.g., military barracks, college dorm). We used this sample to identify units that converted to housing units after the 1980 census.

In area ED's, 4 percent or more of the 1980 census addresses were either incomplete or inadequate, or new construction was not monitored by building permits (most rural areas).

We selected a sample of housing units from the list of units that received long-form questionnaires in several steps. First, we grouped area ED's based on certain characteristics of interest. Then we selected a systematic sample of ED's. We selected a sample of land areas in these ED's. Finally, we selected a sample of housing units that received 1980 census long forms within the land areas.

New construction in permit-issuing areas. The building permit frame covers only nonmobile home new construction. We selected the sample of permit new construction housing units from permits that were issued before, but expected to be completed after, April 1, 1980. In certain permit areas and for structures of certain sizes, we included permits issued as early as March 1979. But, for the most part, we included permits issued since July 1979.

Within each PSU, we selected building permits monthly based on certain geography characteristics. We created clusters of approximately four housing units and subsampled units within these clusters at the rate of 1 in 4, yielding clusters of size 1. The overall probability of selection of these units is about 1 in 2,148.

Housing units missed in the 1980 census. The Census Bureau conducted a special study, called the Housing Unit Coverage Study (HUCS), as part of the 1980 census. This study identified units at addresses missed or inadequately defined in the 1980 census. We included a sample of the units identified in the HUCS in the AHS sample.

Housing units added since the 1980 census. We pick up two other types of units added since the 1980 census: (a) units added within structures containing sample units and (b) whole-structure additions that did not contain living quarters at the time of the 1980 census.

Within-structure additions—These additions have a chance of being in sample because there is at least one unit that is eligible for selection. We identified these additions in units selected from the 1980 census sample, permit new construction, and the HUCS sample. The rules for identifying within-structure additions differed in certain types of areas and frames.

In area ED's, all within-structure additions in structures containing at least one sample unit were interviewed for the AHS.

In address ED's and in the HUCS and building permit frames, we interviewed all within-structure additions in 1- to 15-unit structures containing at least one sample unit for AHS. In 16-or-more-unit structures, we only interviewed units falling on AHS sample lines.

Whole-structure additions—These types of additions are units in structures that contained no living quarters at the time of the 1980 census. We used area sampling methods to identify these in all types of areas. Under area sampling, we list all housing units within a land area and then select a systematic sample.

In address ED's, we used land areas in sample for the Health Interview Survey (HIS). We only used HIS areas that were in AHS PSU's or in HIS PSU's adjacent to AHS PSU's. Only units that were not already assigned to HIS were eligible.

We matched these units to the 1980 census address registers. If the address matched to the census, the unit was ineligible. (Only the basic address, i.e., 801 Main Street, had to match. Apartment number, mobile home site number, etc., did not have to match).

At the time of listing, we screened eligible units further so we only picked up units with no previous chance of selection. (The screening eliminated units such as nonmobile home new construction, which is covered by building permits, and census misses.) We updated these areas in 1991.

In area ED's where new construction is not monitored by building permits, we used all land areas chosen for the area ED sample. We selected an expected four units, using area sampling methods, within these land areas to identify whole-structure additions. However, we did not match this sample to the census. Instead, we screened this sample at the time of listing using criteria similar to those used in address ED's. One important difference to note is that we did not eliminate new construction during the screening process. In 1989, we only updated one-third of all segments (2 of 6 panels). In 1991, we only updated one-sixth of the segments (1 of 6 panels), but we used twice as many units. We updated all segments in 1987.

In area ED's where new construction is monitored by building permits, we only used one-third of the land areas chosen for the area ED sample. We selected an expected eight units using area sampling methods within these areas to identify whole-structure additions. We screened this sample at the time of listing using the same criteria as for address ED's. Again, we did not match this sample to the census. The screening process eliminated nonmobile home new construction since it is covered by the building permit frame. In 1989, we only updated one-half of the areas (1 of 2 panels). In 1991, we updated the other half and increased the expected number of units by 50 percent. In 1987, we updated all segments.

Rural Supplement

We increased the number of sample housing units in rural areas in 1991 by 50 percent to increase the reliability of rural estimates. We only increased the sample for units selected from the 1980 census and new construction in permit-issuing areas. We selected the sample using the

same methods as above for these two types of units. After adding the supplemental sample, the overall probability of selection for rural units increased to 1 in 1,432.

Telephone Interviewing Experiment

We conducted a large-scale Computer Assisted Telephone Interviewing (CATI) experiment as part of the 1991 enumeration for AHS-National. We investigated the effects of CATI interviewing on AHS-National (AHS-N) data. We divided the 1991 sample into six panels. We assigned two of the six panels to a maximum CATI treatment (about 19,800 cases). We assigned the other four panels (about 38,000 units) to a maximum decentralized (local) telephone interviewing treatment (i.e., the non-CATI treatment).

We screened out units in the CATI treatment sample that were ineligible to be interviewed by CATI. We sent these to the field for a personal visit interview. These screened units included the following:

- New construction added since 1989.
- The supplemental rural sample.
- 1989 noninterviews.
- 1989 vacant units.
- 1989 units temporarily occupied by persons with usual residence elsewhere (URE's).
- Households with eight or more members.
- Multiunit mobile homes.
- Special places.
- Unit address/structure type inconsistencies.
- Units interviewed in 1989 that did not have a telephone number where they could be contacted.

The remaining 10,500 units were eligible for CATI. We assigned these units to the Hagerstown, Maryland Telephone Center to attempt CATI. We interviewed about 6,100 of these cases by CATI. This represents about 60 percent of eligible cases and about 33 percent of the CATI treatment sample. We recycled eligible units not interviewed by CATI to the field for a personal visit or decentralized telephone interview.

Within the non-CATI treatment, about 40 percent of the units were interviewed by telephone. We assigned units ineligible for telephone interview, and eligible units that could not be interviewed by telephone, for personal visit interviews.

WEIGHTING

After assigning each unit a weight that reflected the correct probability of selection, the AHS weighting procedure consisted of two phases.

First Phase

In the first phase, we make a series of adjustments to account for units that could not be interviewed for a number of reasons. For each of these adjustments, we compute a factor and apply it to the appropriate units. The factors equal the following ratio:

$$\frac{\text{Housing units to be kept after factor applied} + \text{Housing units to be dropped after factor applied}}{\text{Housing units to be kept after factor applied}}$$

The housing units kept after applying a factor have that factor applied to them. The first of these adjustments, done only in permit segments, accounts for permits that could not be sampled and units that could not be found. These are represented by all other units in permit segments including both interviews and noninterviews (excluding unable-to-locate units).

The second of the adjustments accounts for units in structures built before the 1980 census that could not be found. The unlocatable units are represented by both interviews and noninterviews (excluding unable-to-locate units).

The last of these adjustments accounts for units that could not be interviewed because either no one was home after repeated visits or the respondent refused to be interviewed. When prior-year AHS-N or 1980 census data are available, we use this information to determine the noninterview adjustment cell. The cells include the following characteristics:

- Tenure (i.e., owner or renter).
- Geography.
- Type of housing unit (i.e., mobile home or nonmobile home).
- Units in structure.
- Number of rooms.

When previous data are not available, we compute adjustment factors using more general characteristics such as type of area and type of housing unit (i.e., mobile home, nonmobile home).

Second Phase

The second phase involves a three-stage ratio estimation procedure that adjusts for the following: (a) sampling of nonself-representing PSU's, (b) known sampling deficiencies in new construction, and (c) differences between sample estimates and estimates derived from independent sources for key characteristics.

The first stage of this procedure reduces the portion of the variance resulting from the sampling of nonself-representing PSU's. The procedure accounts for differences that existed at the time of the 1980 census between housing units

estimated from the nonself-representing sample PSU's and the 1980 census count of housing units from all nonself-representing strata. We compute factors accounting for these differences separately for the following characteristics: (a) region, (b) tenure, (c) metropolitan area status, and (d) urban or rural status.

In addition, we use ethnicity (i.e., Hispanic, non-Hispanic) in the South and West regions and race in the South region.

The first-stage factor equals the following ratio:

$$\frac{\text{1980 census housing units for all nonself-representing strata in a cell}}{\text{Number of 1980 housing units in the same cell estimated from the sample nonself-representing PSU's}}$$

We calculate the numerators of the ratios by summing the 1980 census housing unit counts for each cell across all nonself-representing strata. We compute the denominators by weighting the 1980 census housing unit counts from each nonself-representing sample PSU by the inverse of the probability of selection for that PSU. Then we sum the weighted counts across all nonself-representing sample PSU's.

The second stage of the ratio estimation procedure adjusts the AHS sample estimate of new construction (i.e., units built since the 1980 census) to account for known deficiencies (see the section on nonsampling error).

For nonmobile homes, we control the sample estimates to independently derived estimates from the Survey of Construction. For mobile homes, we control the most current sample estimates to independently derived estimates from the Survey of Mobile Home Placements. These estimates are the best estimates available for these types of units.

We compute factors separately for each region. The second-stage factor equals the following ratio:

$$\frac{\text{Independently derived estimate for a cell}}{\text{AHS sample estimate in that cell}}$$

We compute the denominators of the above ratio by summing the existing weight on each record after the first stage of ratio estimation over all records for each cell in each region. The numerators come from either the Survey of Construction or the Survey of Mobile Home Placements.

The third stage of the ratio estimation procedure adjusts the AHS sample estimate of housing units to independently derived current estimates for key characteristics. We believe these characteristics are highly correlated with other characteristics of interest for AHS.

The third stage is done in two steps for occupied units. First, we control the sample estimate of occupied housing units to independently derived estimates for the following characteristics:

- Region.
- Tenure.
- Ethnicity (i.e., Hispanic head of household and non-Hispanic head of household).
- Household status (husband-wife, other male, or other female).
- Age of householder.

Then we apply the factor from this step to the interviewed occupied units. Next, we control the new sample estimate of occupied housing units to independently derived estimates for similar characteristics. We substitute race for ethnicity in this step, but all other characteristics are the same.

We control the sample estimate of vacant housing units to an independently derived estimate for four type-of-vacant cells for each region.

We calculate all third-stage factors similarly using the following ratio:

$$\frac{\text{Independently derived estimate of housing units in a cell}}{\text{AHS sample estimate of housing units in that cell}}$$

For occupied units, we derive the numerators of the factors in three steps. First, we compute an independent estimate of total housing units based on 1990 census data from Population Division. Then we determine the occupied portion of this independent control based on the sample proportion of occupied units. Finally, we allocate the occupied portion of the independent control based on the Current Population Survey distribution for the third-stage occupied cells.

For vacant units, we allocate the vacant portion of the independent control based on the distribution of vacant units from the Housing Vacancy Survey. This survey is a quarterly vacancy survey conducted by the Bureau of the Census.

We compute the denominators of the factors by summing the weights, with all previous factors applied, on all records in a cell. For the Hispanic/non-Hispanic and vacant cells, we use the weight after the second stage of the ratio estimation procedure. For the Black/non-Black cells, we use the weight after the Hispanic/non-Hispanic portion of the third stage of the ratio estimation procedure.

We repeat the second stage and third stage of the ratio estimation procedure to bring the AHS sample estimates into closer agreement with the independent estimates. We used the final weight resulting from all iterations for the tabulations in this report.

As a result of the estimation procedure, the sampling error for most statistics is less than if the sample were simply weighted by the inverse of the probability of selection.

This is the first year we are using controls based on the 1990 census. The method for computing the controls also changed. We believe this method is better than the previous one because, using 1980 census data, it predicted the 1990 census count of housing units better than the previous method. As a result, the 1990-based control is about 2.5 percent lower than the 1980-based control.

We have included 1990-based estimates for 1985, 1987, and 1989 for selected items in table B on page C-1 of appendix C. Estimates of change between 1991 and previous years using data from this table are reliable. However, estimates of change between 1991 and previous years for other items will be understated by about 2.5 percent.

Table 1a. General Characteristics (Items Not Listed in Table 1b)

Characteristic	Publication estimates	Percentages: Value of Y for percent formula
General characteristics not listed below	$Z \times \sqrt{2.288 \times A - .000\,022 \times A^2}$ or $Z \times 2$ *$Z \times \sqrt{2.644 \times A}$	1.000
Black	$Z \times \sqrt{2.705 \times A - .000\,250 \times A^2}$ or $Z \times 3$ *$Z \times \sqrt{3.126 \times A}$	1.087
Hispanic	$Z \times \sqrt{2.363 \times A - .000\,023 \times A^2}$ or $Z \times 2$ *$Z \times \sqrt{2.731 \times A}$	1.016
Hispanic deficiency	$Z \times \sqrt{2.705 \times A - .000\,026 \times A^2}$ or $Z \times 3$ *$Z \times \sqrt{3.126 \times A}$	1.087
Mobile home	$Z \times \sqrt{2.076 \times A - .000\,020 \times A^2}$ or $Z \times 2$ *$Z \times \sqrt{2.399 \times A}$	.953
Urban	$Z \times \sqrt{2.363 \times A - .000\,023 \times A^2}$ or $Z \times 2$ *$Z \times \sqrt{2.731 \times A}$	1.016
Rural	$Z \times \sqrt{1.841 \times A - .000\,018 \times A^2}$ or $Z \times 2$ *$Z \times \sqrt{2.127 \times A}$	.897
In (P)MSA—Central city	$Z \times \sqrt{2.363 \times A - .000\,023 \times A^2}$ or $Z \times 2$ *$Z \times \sqrt{2.731 \times A}$	1.016
In (P)MSA—Suburbs	$Z \times \sqrt{1.999 \times A - .000\,019 \times A^2}$ or $Z \times 2$ *$Z \times \sqrt{2.310 \times A}$	.935
Outside (P)MSA's	$Z \times \sqrt{2.173 \times A + .000\,922 \times A^2}$ or $Z \times 2$ *$Z \times \sqrt{2.511 \times A}$	.975
Northeast	$Z \times \sqrt{1.999 \times A - .000\,095 \times A^2}$ or $Z \times 2$ *$Z \times \sqrt{2.310 \times A}$	.935
Midwest	$Z \times \sqrt{2.288 \times A - .000\,092 \times A^2}$ or $Z \times 2$ *$Z \times \sqrt{2.644 \times A}$	1.000
South	$Z \times \sqrt{2.435 \times A - .000\,066 \times A^2}$ or $Z \times 2$ *$Z \times \sqrt{2.814 \times A}$	1.032
West	$Z \times \sqrt{2.705 \times A - .000\,126 \times A^2}$ or $Z \times 3$ *$Z \times \sqrt{3.126 \times A}$	1.087

*Use this formula for journey-to-work estimates only.

Table 1b. Neighborhood and Heating Equipment Characteristics

Characteristic	Publication estimates	Percentages: Value of Y for percent formula
Other neighborhood and heating equipment	$Z \times \sqrt{2.829 \times A - .000\,027 \times A^2}$ or $Z \times 3$ *$Z \times \sqrt{3.269 \times A}$	1.112
Black	$Z \times \sqrt{3.344 \times A - .000\,309 \times A^2}$ or $Z \times 3$ *$Z \times \sqrt{3.864 \times A}$	1.209
Hispanic	$Z \times \sqrt{3.344 \times A - .000\,032 \times A^2}$ or $Z \times 3$ *$Z \times \sqrt{3.864 \times A}$	1.209
Mobile homes: Neighborhood	$Z \times \sqrt{2.566 \times A - .000\,025 \times A^2}$ or $Z \times 3$ *$Z \times \sqrt{2.965 \times A}$	1.059
Equipment	$Z \times \sqrt{4.358 \times A - .000\,042 \times A^2}$ or $Z \times 4$ *$Z \times \sqrt{5.036 \times A}$	1.380
Urban	$Z \times \sqrt{3.344 \times A - .000\,032 \times A^2}$ or $Z \times 3$ *$Z \times \sqrt{3.864 \times A}$	1.209
Rural: Neighborhood	$Z \times \sqrt{2.138 \times A - .000\,020 \times A^2}$ or $Z \times 2$ *$Z \times \sqrt{2.471 \times A}$	.967
Equipment	$Z \times \sqrt{3.632 \times A - .000\,035 \times A^2}$ or $Z \times 4$ *$Z \times \sqrt{4.197 \times A}$	1.260
In (P)MSA—Central city	$Z \times \sqrt{3.344 \times A - .000\,032 \times A^2}$ or $Z \times 3$ *$Z \times \sqrt{3.864 \times A}$	1.209
In (P)MSA—Suburbs	$Z \times \sqrt{2.829 \times A - .000\,027 \times A^2}$ or $Z \times 3$ *$Z \times \sqrt{3.269 \times A}$	1.112
Outside (P)MSA	$Z \times \sqrt{6.517 \times A + .001\,275 \times A^2}$ or $Z \times 7$ *$Z \times \sqrt{7.531 \times A}$	1.688
Northeast	$Z \times \sqrt{2.829 \times A - .000\,134 \times A^2}$ or $Z \times 3$ *$Z \times \sqrt{3.269 \times A}$	1.112
Midwest	$Z \times \sqrt{2.829 \times A - .000\,113 \times A^2}$ or $Z \times 3$ *$Z \times \sqrt{3.269 \times A}$	1.112
South: Neighborhood	$Z \times \sqrt{2.829 \times A - .000\,076 \times A^2}$ or $Z \times 3$ *$Z \times \sqrt{3.269 \times A}$	1.112
Equipment	$Z \times \sqrt{4.805 \times A - .000\,130 \times A^2}$ or $Z \times 5$ *$Z \times \sqrt{5.552 \times A}$	1.449
West	$Z \times \sqrt{3.344 \times A - .000\,155 \times A^2}$ or $Z \times 3$ *$Z \times \sqrt{3.864 \times A}$	1.209

*Use this formula for journey-to-work estimates only.

Table 2. Standard Errors of Bias Resulting From Incomplete Data

(In thousands)

Publication estimate	Standard error of bias	Sampling error[1]
0	126	2
10	126	5
25	126	8
50	127	11
100	129	15
250	135	24
500	144	34
1,000	162	48
2,500	216	75
5,000	307	104
10,000	489	144
15,000	670	171
25,000	1,033	208
40,000	1,578	237
50,000	1,941	244
75,000	1,200	219
90,000	655	166
100,000	292	94
104,591	126	2

[1]This is an example of the magnitude of the sampling error. These were calculated using the first formula from table 1a.