



Item Nonresponse and Imputation: 1997 to 2013

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1. Overview

The purpose of this document is to explain how the Department of Housing and Urban Development (HUD) and the U.S. Census Bureau (Census Bureau) implemented imputation strategies for item non-response in the American Housing Survey (AHS) for 1997 through 2013. While many of the same techniques were used from 1985 through 1996, this guide does not exhaustive accounting of imputation during that period, and as such, applies only to 1997 through 2013.

The AHS includes more than one-hundred questions covering a broad array of topics. In some instances, households refuse to respond to the entire survey. This is called unit nonresponse. HUD and the Census Bureau use a statistical technique called non-response adjustment to ensure that estimates produced from AHS data reflect both responding and nonresponding households.

When households chose to respond to the AHS, they generally provide answers to all survey questions. However, for some households, the Census Bureau is unable to obtain a response to every survey question. This is called item nonresponse. There are at least four reasons why item nonresponse occurs:

- A household chooses not to answer a question.
- A household did not know the answer to a question.
- A household is not asked the question because the household quit an interview early but answered enough questions to be considered a complete interview.
- A household was not eligible to be asked a question at the time of the interview but was edited in a way after collection that made the housing unit eligible to be asked the question.

A desirable outcome for many surveys is to have complete responses for each survey item (variable). When a survey variable includes missing responses, it can often be difficult for beginner or novice survey data users to adjust their analysis to account for the missing responses. To improve the usability of survey data, survey managers often “fill in” the missing data. This process is called imputation. Imputation improves the completeness and consistency of survey data and prepares the survey data for weighting and estimation processes.

HUD and the Census Bureau use imputation to fill in missing responses in the AHS. However, it is important to note that missing responses are imputed in the AHS, but only for certain variables. In fact, most AHS variables with missing responses are not imputed.

Section 2 of this help guide describes the general imputation techniques used in the AHS from 1997 to 2013. Section 3 describes the specific imputation technique for each public use file (PUF) variable and is organized by subsection (PUF topic) and exhibit table (subtopic).

2. Imputation Techniques in the AHS

There are numerous ways to impute missing responses and the method chosen often depends on the type of missing data. For the AHS, four different imputation techniques are used. The following section describes and summarizes the different imputation procedures.



2.1. Deductive Imputation

This method of imputation uses reported pieces of information to fill in missing values. For example, if payment amount on a mortgage is missing, but original loan amount, payment frequency, interest rate, and term are all reported we will use a financial formula to fill in the missing payment amount.

We also do a type of weighted coin flip to fill in some missing values for variables where we know some information about the population. For example, suppose an AHS respondent refused to answer the question about whether they owned or rented the home. We know from other data sources that about 60 percent of occupied housing units are owners and 40 percent are renters. We would then assign a 60 percent chance of filling in this missing observation as an owner (and a 40 percent chance that they are a renter.)

2.2. Cold Deck Imputation

The AHS is a longitudinal survey, meaning most housing units are surveyed every two years. The AHS includes questions about features of the housing unit. Some features of housing units that are part of the AHS sample not expected to change over time. When a household does not answer a question about a feature of the housing unit and the question is about a feature that is not expected to change over time and there is a response to the question from a prior survey, the missing value is imputed with a value collected in a prior interview of the same housing unit. For example, the year the housing unit was built is not expected to change. If a household refuses or does not know the year built, a prior reported value will be used if it is available. This form of imputation is not the focus of this document, as it is taken care of by the interviewing instrument or consistency edits that take place prior to other forms of imputation.

2.2. Hot Deck Imputation

In this method of imputation, a household with a missing value for an item (recipient) “borrows” a value from another household who provided a valid response for that item (donor). The hot deck imputation procedure is implemented in a way that attempts to match a recipient household with a donor household based on a common set of characteristics, referred to as the hot deck.

Before imputation, all records are sorted by an internal variable that contains some geographic information. This sorting keeps donor and recipient records geographically close to each other. The geography used to sort the records for imputation are state and county. After sorting is complete variables are imputed one at a time in a single pass through the data. For example, suppose a household reported their home was constructed in 2010 and has three bedrooms, but did not provide a valid response for number of bathrooms. In a hot deck procedure, the hot deck could be based on year built and number of bedrooms, such that the pool of potential donors most likely to be matched to the recipient are those with a similar year built and similar number of bedrooms, along with being close geographically.

In the AHS, the variables that define the hot deck are chosen because they are expected to be correlated, or more generally, they are associated, with the variable being imputed.

2.2. Special Imputation

For three specific groups of variables, specialized imputation procedures are applied. These groups are income, utilities, and home improvement. The special procedures are described in subsequent sections.



3. Specific Imputation Strategy

This subsections in this section (3.1, 3.2, etc.) correspond to topics in the AHS PUF. Each subsection has one or more exhibit tables corresponding to subtopics within the subsection’s topic. Also, it is important to note that the order in which variables are imputed is based on internal decisions by AHS managers and does not follow the topic/subtopic format.

3.1. Demographics Topic

Exhibit 3.1. Person Demographics Subtopic

PUF Variable	Description	Imputation Method
MOVE	Year person moved in	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
MOVM	Month person moved in	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).

3.2. Equipment and Appliances Topic

Exhibit 3.2. Appliances Subtopic

PUF Variable	Description	Imputation Method
BURNER	Unit has working built-in cooking burners	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
COOK	Unit has working cook stove or range/oven	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
CFUEL	Type of fuel used most for cooking	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
DFUEL	Fuel used by clothes dryer	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
DISH	Unit has working dishwasher	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
DRY	Unit has working clothes dryer	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
FRIDGE	Flag indicating unit has a working refrigerator	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
SINK	Flag indicating unit has a kitchen sink	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
OVEN	Unit has a working microwave oven	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
WASH	Unit has a working washing machine	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).



Exhibit 3.3. Cooling Subtopic

PUF Variable	Description	Imputation Method
AFUEL	Type of fuel used for air conditioning	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
AIR	Room air conditioner	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
AIRSYS	Central air conditioner	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
NUMAIR	Number of room air conditioners	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
OAFUEL	Fuel used by other central a/c unit	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).

Exhibit 3.4. Heating Subtopic

PUF Variable	Description	Imputation Method
FPLWK	Flag indicating unit has a useable fireplace	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
GASPI2	Source of gas heat for vacant units	Deductive imputation
GASPIP	Gas from underground pipes or bottles	Hot deck imputation using tenure, main fuel use, number of bedrooms, and number of occupants
HFUEL	Type of main heating fuel	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
HEQUIP	Type of main heating equipment	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).

Exhibit 3.5. Water and Sewer Subtopic

PUF Variable	Description	Imputation Method
WATER	Source of water for unit	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
WFUEL	Fuel used most to heat water	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).

3.3. Home Improvement Topic

Exhibit 3.6. Job Specific Subtopic

PUF Variable	Description	Imputation Method
RAD	Cost of alteration/repair	Hot deck imputation using weighted median of combined home improvement job costs, property value, and DIY/PRO job.
RAH	Household member performed alteration/repair	Logistic regression model using home improvement job type and cost, urban/rural status, and structural type

3.4. Housing Costs Topic

Exhibit 3.7. Owner's Purchase and Value Subtopic

PUF Variable	Description	Imputation Method
VALUE	Current market value of unit	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, vacancy status, number of occupants, and demographic information (e.g. age, race).



Exhibit 3.8. Total Housing Cost Subtopic

PUF Variable	Description	Imputation Method
BUYI	Household has homeowners insurance	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
RENT	Monthly rent amount	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, vacancy status, number of occupants, and demographic information (e.g. age, race).

Exhibit 3.9. Utility Cost Subtopic

PUF Variable	Description	Imputation Method
AMTE	Average monthly cost of electricity	Model based imputation using Residential Energy Consumption Survey billing data and other housing unit and household characteristics such as number of rooms and number of persons.
AMTF	Annual cost of other fuels	Hot deck imputation using tenure, main fuel use, number of bedrooms, and number of occupants.
AMTG	Average monthly cost of gas	Model based imputation using Residential Energy Consumption Survey billing data and other housing unit and household characteristics such as number of rooms and number of persons.
AMTO	Annual cost of fuel oil	Hot deck imputation using tenure, main fuel use, number of bedrooms, and number of occupants.
AMTT	Annual cost of garbage & trash	Hot deck imputation using tenure, main fuel use, number of bedrooms, and number of occupants.
AMTW	Annual cost of water & sewage	Hot deck imputation using tenure, main fuel use, number of bedrooms, and number of occupants.
BUYE	Pay for electricity separately	Hot deck imputation using tenure, main fuel use, number of bedrooms, and number of occupants.
BUYE2	Pay for electricity separately	Hot deck imputation using tenure, main fuel use, number of bedrooms, and number of occupants.
BUYF	Pay for other fuels separately	Hot deck imputation using tenure, main fuel use, number of bedrooms, and number of occupants.
BUYF2	Pay for other fuels separately	Hot deck imputation using tenure, main fuel use, number of bedrooms, and number of occupants.
BUYG	Pay for gas separately	Hot deck imputation using tenure, main fuel use, number of bedrooms, and number of occupants.
BUYG2	Pay for gas separately	Hot deck imputation using tenure, main fuel use, number of bedrooms, and number of occupants.
BUYO	Pay for fuel oil separately	Hot deck imputation using tenure, main fuel use, number of bedrooms, and number of occupants.
BUYO2	Pay for fuel oil separately	Hot deck imputation using tenure, main fuel use, number of bedrooms, and number of occupants.
BUYT	Pay for garbage/trash separately	Hot deck imputation using tenure, main fuel use, number of bedrooms, and number of occupants.
BUYT2	Pay for garbage/trash separately	Hot deck imputation using tenure, main fuel use, number of bedrooms, and number of occupants.
BUYW	Pay for water/sewage separately	Hot deck imputation using tenure, main fuel use, number of bedrooms, and number of occupants.
BUYW2	Pay for water/sewage separately	Hot deck imputation using tenure, main fuel use, number of bedrooms, and number of occupants.



3.5. Housing Problems Topic

Exhibit 3.10. Electrical Problems Subtopic

PUF Variable	Description	Imputation Method
NOWIRE	Flag indicating electrical wiring concealed by walls	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
PLUGS	Flag indicating every room has working electrical plug	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).

Exhibit 3.11. Pests Subtopic

PUF Variable	Description	Imputation Method
EROACH	Number of times there were signs of live or dead cockroaches in last 12 months	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
EVROD	Evidence of rodents in unit	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
M12ROACH	Roaches seen in unit until recently	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
M12ROD	Rodents seen in unit recently	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
RATFREQ	Frequency of evidence of rats	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
ROACHFRQ	Frequency of evidence of roaches	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).

Exhibit 3.12. Plumbing Problems Subtopic

PUF Variable	Description	Imputation Method
HOTPIP	Unit has hot & cold running water	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
IFSEW	Sewage system broke down	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
NUMSEW	Number of sewage system breakdowns	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).

Exhibit 3.13. Structural Problems Subtopic

PUF Variable	Description	Imputation Method
BIGP	Area of peeling paint larger than 8 x 11	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
CRACKS	Open cracks wider than dime	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
HOLES	Holes in floor	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).



3.6. Income Topic

From 1997 to 2013, the income variables were imputed using a standard hot deck imputation method. Due to differences in median income on the AHS, the income portion of the AHS questionnaire was redesigned for the 2005 survey year and a new imputation method was implemented at the same time. As developed by Susin (2005), the AHS uses a hybrid of a regression model and a hot deck procedure to impute the variables that represent the twelve types of income. For types of income that must have values greater than or equal to zero, the imputation had two steps, as defined below:

Step 1: Impute the presence of income.

Separate logistic regression models are estimated for each of the twelve types of income. The model predicts the probability of the presence of any income of the given type. The model does not predict exact 0/1 binary values that represent presence/no presence of income, but estimates the probability of having income. The presence of income is imputed by randomly generating a 0/1 variable given the estimated probability of the presence of income.

Step 2: Impute income amount.

First, a regression model is estimated for each income type that predicts the given income amount using the donor cases. Second, the donors and the recipients are split into hot deck cells using the predicted values from the regression. Susin (2005) suggested forming cells with about 500 records to ensure that each cell had plenty of donors. Third, the recipients are imputed with the hot deck using the cells formed by the predicted values. Since the records are also sorted with respect to geography, the last donor will typically be geographically close to the recipient.

Susin (2005) used the term “triangular regression-based hot deck” because as each type of income is imputed, it is added to the model for the next type of income. For completeness, we mention that the models of Step 1 are not triangular in that they do not use the previously imputed variables. A link to the paper describing the methodology can be found in the references section of this document.

Most of the variables on the PUFs are not person level; rather, they are created from person level variables that may have been imputed according to the method described above. Even though many of these variables are not imputed directly, they are considered to be imputed if their components are imputed.



Exhibit 3.14. Person Income Subtopic

PUF Variable	Description	Imputation Method
PQOTHNR	Other income received by nonrelative	Hot deck imputation based on a linear regression model using demographic variables, work status, and various others.
PQSAL	Wages/salary received by reference person/relative	Hot deck imputation based on a linear regression model using demographic variables, work status, and various others.
PQSALNR	Salary received by nonrelative	Hot deck imputation based on a linear regression model using demographic variables, work status, and various others.
PQSELF	Person's self-employment income (past 12 months)	Hot deck imputation based on a linear regression model using demographic variables, work status, and various others.
SAL	Person's wages or salary income (past 12 months)	Hot deck imputation based on a linear regression model using demographic variables, work status, and various others.

Exhibit 3.15. Total Household Income Subtopic

PUF Variable	Description	Imputation Method
QALIM	Received alimony or child support. Recode based on PQALIM.	Hot deck imputation based on a linear regression model using demographic variables, work status, and various others.
QDIV	Received dividends from stock. Recode based on PQDIV.	Hot deck imputation based on a linear regression model using demographic variables, work status, and various others.
QINT	Received interest from savings, cd, etc. Recode based on PQINT.	Hot deck imputation based on a linear regression model using demographic variables, work status, and various others.
QOTHER	Received unemployment/vet payments/other inc. Recode based on PQOTHER.	Hot deck imputation based on a linear regression model using demographic variables, work status, and various others.
QRENT	Received rental income. Recode based on PQRENT.	Hot deck imputation based on a linear regression model using demographic variables, work status, and various others.
QRETIR	Received retirement or survivor pension. Recode based on PQRETIR.	Hot deck imputation based on a linear regression model using demographic variables, work status, and various others.
QSELF	Received self-employment income. Recode based on PQSELF.	Hot deck imputation based on a linear regression model using demographic variables, work status, and various others.
QSS	Received social security or pension. Recode based on PQSS.	Hot deck imputation based on a linear regression model using demographic variables, work status, and various others.
QSSI	Received Supplemental Security Insurance Income	Hot deck imputation based on a linear regression model using demographic variables, work status, and various others.
QWELF	Received AFDC, TANF or other public assistance or welfare program payments. Recode based on PQWELF.	Hot deck imputation based on a linear regression model using demographic variables, work status, and various others.
QWKCMP	Received workers compensation or other disability payments. Recode based on PQWKCMP.	Hot deck imputation based on a linear regression model using demographic variables, work status, and various others.
ZINC	Family Income (amount of income of reference person and related household members)	Hot deck imputation based on a linear regression model using demographic variables, work status, and various others.
ZINC2	Total combined income of all household members	Hot deck imputation based on a linear regression model using demographic variables, work status, and various others.



3.7. Mortgage Details Topic

Exhibit 3.16. Mortgage Origination Subtopic

PUF Variable	Description	Imputation Method
AMMORT	Amount of 1st mortgage when acquired	Hot deck using number of mortgages.
AMRTZ	Years needed to pay off 1st mortgage	Hot deck imputation using number of years paid on mortgage.
INTR	Interest rate of 1st mortgage	Hot deck imputation using number of years paid on mortgage.
TERM	Term of 1st mortgage	Hot deck imputation using number of years paid on mortgage.
PMT	Monthly payment for 1st mortgage	Deductive imputation.

3.8. Neighborhood Features Topic

Exhibit 3.17. General Subtopic

PUF Variable	Description	Imputation Method
TPARK	Number of mobile homes in group	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).

3.9. Occupancy and Tenure Topic

Exhibit 3.18. Tenure Subtopic

PUF Variable	Description	Imputation Method
CONDO	Flag indicating unit is a condominium	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
OWNHERE	Owner/resident manager lives on-site	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
TENURE	Owner or renter status of unit	Deductive imputation.

Exhibit 3.19. Vacancy Characteristics Subtopic

PUF Variable	Description	Imputation Method
MOVAC	# months unit has been vacant	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
VACANCY	Vacancy status	Deductive imputation.

3.10. Structural Topic

Exhibit 3.20. Exterior Features Subtopic

PUF Variable	Description	Imputation Method
LOT	Square footage of lot	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
PORCH	Flag indicating unit has porch or deck or balcony or patio	Deductive imputation.



Exhibit 3.21. General Subtopic

PUF Variable	Description	Imputation Method
BUILT	Year unit was built	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, vacancy status, number of occupants, and demographic information (e.g. age, race).
FLOORS	Number of floors within the unit	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
NUNIT2	Are these living quarters in a...	Hot deck imputation based on number of floors, tenure, and vacancy status.
NUNITS	Number of units in building	Hot deck imputation based on number of floors, tenure, and vacancy status.
TYPE	Housing unit type	Hot deck imputation based on number of floors, tenure, and vacancy status.

Exhibit 3.22. Interior Features Subtopic

PUF Variable	Description	Imputation Method
BATHS	Number of full bathrooms in unit	Hot deck imputation based on structure type, number of occupants, tenure, and vacancy status.
BEDRMS	Number of bedrooms in unit	Hot deck imputation based on structure type, number of occupants, tenure, and vacancy status.
BSINK	Unit has a bathroom sink	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
CELLAR	Unit has a basement	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
DENS	Number of dens or libraries in unit	Hot deck imputation based on structure type, number of occupants, tenure, and vacancy status.
DINING	Number of dining rooms in unit	Hot deck imputation based on structure type, number of occupants, tenure, and vacancy status.
FAMRM	Number of family rooms, great rooms, or TV rooms in unit	Hot deck imputation based on structure type, number of occupants, tenure, and vacancy status.
HALFB	Number of half bathrooms in unit	Hot deck imputation based on structure type, number of occupants, tenure, and vacancy status.
KITCH	Number of kitchens in unit	Hot deck imputation based on structure type, number of occupants, tenure, and vacancy status.
LAUNDY	Number of laundry or utility rooms in unit	Hot deck imputation based on structure type, number of occupants, tenure, and vacancy status.
LIVING	Number of living rooms in unit	Hot deck imputation based on structure type, number of occupants, tenure, and vacancy status.
OTHFN	Number of other finished rooms in unit	Hot deck imputation based on structure type, number of occupants, tenure, and vacancy status.
RECRM	Number of recreation rooms in unit	Hot deck imputation based on structure type, number of occupants, tenure, and vacancy status.
TOILET	Unit has a flush toilet	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
TUB	Unit has a bathtub or shower	Hot deck imputation using structure type, tenure, property value or rent, number of bedrooms, and demographic information (e.g. age, race).
OTHRUN	Number of other unfinished rooms in unit	Hot deck imputation based on structure type, number of occupants, tenure, and vacancy status.



4. References

Susin, Scott. 2005. "Imputation via Triangular Regression-Based Hot Deck." U.S. Census Bureau. <https://www.census.gov/programs-surveys/ahs/research/publications/hotdeck.html>.

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