A Review of the Cell Phone Sample Component of the California Health Interview Survey

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Abstract

This paper describes the history of cell phone sample component of the California Health Interview Survey (CHIS). CHIS is a random digit dialing (RDD) telephone survey of California's population conducted since 2001. The objectives of CHIS are to examine issues in public health and health care and to monitor changes over time for Californians.

In the last decade, the increasing noncoverage bias in landline surveys is mainly the result of the increased popularity of cell phone use accompanied by a rise in the number of cell phone-only households. This noncoverage problem has been formally addressed in CHIS beginning in 2007 after the completion of a pilot cell phone sample used to interview cell-only households in 2005. In 2007, an expanded cell phone sample was used to supplement the landline sample with cell-only households. In 2009 and 2011, the cell phone sample was modified to include respondents with both telephone services. In 2011, the cell phone sample was expanded to include targets at the county level. This paper describes our experience with the different methodologies used in sampling and estimation for this dual frame approach used in CHIS.

Key Words: Cell phone sample; health survey, multiple frame survey

1. Introduction

The California Health Interview Survey (CHIS) is a random digit dialing (RDD) telephone survey of California's population first administered in 2001. CHIS is the largest health survey ever conducted in any state and one of the largest health surveys in the nation. It is a collaborative project of the UCLA Center for Health Policy Research, the California Department of Health Services, and the Public Health Institute. In addition to California state, funding for CHIS comes from sources including federal government agencies and private foundations. Westat is the data-collection contractor and develops the weights for analysis of the data collected in CHIS.

CHIS collects extensive information on public health, health status and prevalence of chronic conditions, health-related behaviors, health insurance coverage, and access to health care services. Data from CHIS supports the production of estimates for the state, many counties, and for groups of smallest counties in California. The survey also supports the study of the characteristics for the major racial and ethnic groups and a number of smaller ethnic groups within the state. Adults, parents or guardians of children,

and adolescents within California households are eligible for sampling.

Since the first CHIS administration in 2001, two developments have challenged the data quality of CHIS and other telephone surveys: declining response rates and the continuous growth of cell phone-only households. Early research on the cell-only population found evidence that they differ systematically from the population with a landline telephone on important demographic and health variables (Tucker, Brick, and Meekins, 2007). For example, adults in cell-only households tend to be younger, non-white, and more urban than adults with landline telephones. Health indicators, such as health insurance coverage and tobacco consumption, are also found to be different between these groups. As a result, estimates from surveys that sample only landline telephones are increasingly subject to potential noncoverage bias.

This paper describes how a cell phone sample component has been incorporated in CHIS to address the challenge of undercoverage from increasing cell phone use. Section 2 describes the issues associated with sampling cell phones. Sections 3, 4, 5, 6, and 7 present details of the telephone samples in the 2001, 2003, 2005, 2007, 2009 and 2011 data collection cycles. The last section summarizes what has been learned and describes challenges for future cycles of CHIS.

2. Issues in Landline and Cell Phone Samples

List-assisted random digit dialed sampling has been the standard method for telephone surveys, one of the most cost efficient modes of collecting data, since the early nineties (Casady and Lepkowski, 1993). The objectives in CHIS are the collection of extensive health information data from a diverse population in multiple languages at the county level or other small geographies. To meet these goals, CHIS was initially designed as a list-assisted RDD telephone survey. To address the increasing prevalence of cell-only households, a cell phone sample was piloted in 2005 and the first cell samples were implemented in 2007.

The sample designs of the landline and cell phone RDD components in CHIS are very similar. Each first samples telephone numbers and then samples one adult per household. For the landline component and later implementations of the cell phone component, children and adolescents are also sampled. Although both components have similar designs, different issues arise during the implementation of each sample. First, the frame for the landline sample is created somewhat differently than it is for the cell phone sample. The list-assisted method used in landline sampling uses 100-series blocks (first eight digits) of telephone numbers and random samples are taken from those blocks that have at least one telephone number listed in white page directories. On the other hand, the cell phone sample is selected from 1000-series blocks (first seven digits) dedicated to wireless services in the Telecordia database. These include exchanges with type of service NXXTYPE 04, 55, 60, and PCS 65, or 68. No directory listings are available to support the design option used for the landline sample.

In general. telephone numbers are assigned separately for cell phones and landlines. Because of this, non-overlapping frames of landlines and cell phones could be constructed. However, in 1996, the U.S. Federal Communications Commission (FCC) mandated that all telephone service providers allow for “Local Number Portability” (LNP). According to this mandate, customers can switch between service providers or service types, keeping their original telephone number. As a result, the sampling frames

for cell phones and landlines are not necessarily cleanly divided. There may be telephone numbers in the landline frame that are actually cell phone numbers. These "ported" numbers can be identified by the sampling vendor by matching to a database of cell phone numbers. Prior to 2005 ported numbers were excluded from CHIS samples, but beginning with 2005 cell phone pilot these cases have been dialed as part of the CHIS cell samples.

2.1 Geography

Another frame related issue is the lack of geographic information for cell phone samples. Although the cell phone samples are drawn from exchanges assigned to wireless service, unlike landline phone numbers, the geographic area covered by these exchanges does not necessarily indicate where the owner of the number resides. This is because the cell phone exchange generally corresponds to where the cell phone was purchased or activated, and not where the person lives as with landline numbers. For a survey like CHIS that produces state and county-level estimates, this creates several issues. First, it makes it difficult to target households at levels of geography lower than the state; a significant number of respondents may live in an area different from where their phone was purchased. Additionally, it is also possible for someone with a California cell phone to live in another state, which would render the individual ineligible for CHIS. Each of these situations can only be determined during the interview.

A more serious potential problem with geographic mobility of cell phones is that some California residents have their cell phone numbers assigned in another state. Cell phone numbers of individuals residing in California but with telephone numbers assigned to a different state are not on the sampling frame, and there is no economically viable method to reach this part of the population. There is no estimate of this undercoverage regarding the CHIS, but Fleeman (2007) reported that about 5 percent of respondents in a national sample of cell phone numbers reside in a state different from the one used to select the sample.

2.2 Data Collection Methods

Frame construction is not the only difference between the landline and cell phone samples. Differences also exist in how the samples can be processed once the sample has been selected. Landline samples are able to incorporate a number of procedures that increase sample yield. These include specialized screening processes to identify businesses by matching to yellow pages and non-productive numbers by conducting tritone tests by an automatic dialer. In CHIS these processes remove approximately half of the sampled numbers, which greatly reduces the number of non-productive calls. These processes cannot be implemented in cell phone samples because the lack of equivalent yellow pages directory and regulations from the FCC in the U.S. Telephone Consumer Protection Act (TCPA) which ban the use of autodialers and predictive dialers for cell phones. As a result, more of the nonresidential sample is dialed for the cell phone sample than in the landline sample.

In addition to being able to screen for unproductive sample records, a proportion of the landline telephone numbers can also be matched to addresses using white page directories. As there is not a telephone directory available for cell phones, it is not possible to identify any addresses for the cell phone cases a priori. In CHIS, pre-notification letters and a token incentive are mailed to those sampled household with an address prior to the telephone number being called. This effort has been shown to increase response rates in CHIS. Respondents sent the pre-notification letter and

incentive have consistently responded at a greater rate than those who were not able to receive the letter.

Although respondents in the CHIS cell phone sample do not get a pre-paid incentive, respondents to the cell phone screener and extended interviews are provided a post-paid incentive. Early on this was due to the nature of payment contracts of cellular service, where calls to a cell phone incurred costs to the subscriber thereby increasing their burden. The use of incentive for the CHIS cell phone sample may be re-evaluated as the payment plans for cell phone evolve.

Another issue related to the contact protocols for the cell phone sample in CHIS is related to the risk of injury posed by contacting someone on their cell phone when respondents are performing activities that require their full attention such as driving a vehicle. Special contact protocols for cell phone samples have been developed and implemented since the cell phone pilot in 2005. These protocols required training interviewers about the problem and offering to call back respondents at a more convenient time.

2.3 Within Household Sampling

There is another important distinction between landline and cell phone samples. This occurs at the second stage of sampling. In the landline survey, the sampled unit is always a household, and one adult is randomly selected for the extended interview from all adults in the household. In contrast, the sampled unit in a cell phone survey is not necessarily a household (i.e., a cell phones are more often a personal rather than household device). This difference requires separate sampling protocols for each telephone type.

Though it is often true that a cell phone is a personal device and thus no subsampling is required, there is a subset of cell phone numbers which are shared. The sharing relationship of the cell phone must be determined during the screener interview to properly sample the corresponding adults. In CHIS, once it is determined that a cell phone is shared, a slightly modified version of the sampling protocol used for landlines is employed in which all household members have a chance for selection.

The sampling of children and adolescents requires special care. In the landline sample, a landline number represents an entire household, and the children and adolescents in the household have one chance of selection—through the one telephone number on the landline frame. In the cell phone sample, it is often true that cell phones are personal devices and thus represent only one person. In CHIS, the sampling of children and adolescents is tied to the sampling of related adults. If there are two related adults in the household and each adult has a personal cell phone, the child or adolescent will have a chance of selection through each adult.

2.4 Allocation

The last issue related to the implementation of a cell phone sample is the allocation of the sample between the cell phone and landline component. Before addressing the allocation, we need to introduce the two approaches used when conducting a dual frame landline and cell survey. In the first approach, the screener method, only respondents in cell-only households are interviewed in the cell phone survey and those that have both types of service are ineligible for the extended interview. In the second approach, the overlap method, those with both a landline and a cell phone are also eligible for the extended

interview. For a more detailed discussion of the screener and overlap methods see Brick, Edwards, and Lee (2007).

There are three aspects that determine the sample allocation between landline and cell phone samples: cost, variance, and bias. The cost of completing a cell phone survey is generally greater than the cost of completing a landline survey. Cost will also differ depending on whether you use the screener or overlap method. In terms of variance, when the cell phone sample size deviates from a proportionally allocated sample of landline and cell frames (often due to cost considerations), the design effect that is the result of the differential sampling increases the variance of the estimates. Looking next at bias, if it is assumed that dual use households that are surveyed produce the same estimates, whether they were sampled in the landline or cell frame, then there is no bias. However, it has been observed that response rates are related to an individual's usage of landline and cell phones, with those who use their cell phones for most of their calls more likely to respond to the cell survey and those that use their landline most are more likely to respond to the landline survey. If survey responses for these subgroups are different based on the frame from which they were sampled then the estimates may be biased. Brick et al (2011) provides a detailed discussion of the impact that cost, variance, and bias have on the design of a cell phone survey.

3. CHIS 2001, 2003, and 2005

In CHIS 2001, the problem of undercoverage from households without a landline telephone was addressed through weighting (Flores Cervantes et al., 2002). It was not until 2003 that the potential problem of undercoverage due to the increasing popularity of cell phone use was identified. The estimate of adults without telephone service in 2003 was 1.6 percent while the estimate of cell-only adults was 2.9 percent (Blumberg et al., 2008). In 2005, the percentages were 1.5 and 6.7 respectively.

In 2003 and 2005, the undercoverage due to households without a landline, which includes cell-only households, was addressed though ratio weighting adjustment in the form of an additional raking dimension. The adjustment was a variation of the calibration method proposed by Liu et al., (2004). In this method, calibration cells are created explicitly for adjusting weights for households without a landline telephone. The categorical search algorithm CHAID (Kass, 1980) was used to compute the propensity of being a telephone household using an external file that includes all households. Cells that are homogeneous with respect to telephone status are formed by grouping cases with similar propensities.

In the last step of weighting, the weights were raked to control totals by age groups, gender, race-ethnic groups, and geography in addition to the additional dimension. This approach had some limitations. First, the survey and the external control files must both contain all the variables that are used to compute the predicted propensities. The second limitation is related to the consistency of the estimates between the survey file and the control file. However, given that the percentage of cell-only adults more than doubled in the previous two years, this weighting approach to adjust for cell-only households was abandoned in favor of a cell phone sample, although the weighting adjustment for households with no telephone service still remains in later cycles of CHIS.

4. CHIS 2005 Pilot Cell Phone Sample

A pilot study of adults in cell-only households was conducted in CHIS 2005. The goal of the study was to evaluate the feasibility of sampling and interviewing adults in households with only cell phones in future administrations of the CHIS (Brick et al., 2007). The aim of the pilot study was to complete 100 interviews with adults who lived in households with only cell phones. The pilot was a statewide sample with no geographic quotas. Although sampling weights were produced for this sample, they were not combined with the CHIS 2005 landline sample for the production of estimates.

A sample of 5,200 telephone numbers was selected from the cell phone frame and an additional 671 ported cell phone numbers in the RDD landline sample (see Section 2) was included. These cell phone numbers had been excluded from the CHIS 2005 landline sample and were added to the cell phone pilot study. As a result, the total sample size for the study was 5,871 numbers. However, the target of 100 completed interviews could be reached with a smaller sample; as a result, the last 613 telephone numbers were not dialed as part of the pilot.

Once the sampled telephone number was determined to be a household, then it was classified by telephone status as cell-only household or having both a cell phone and a landline. If the household was classified as being cell-only, then it was considered eligible for the extended interview and one adult was sampled. This approach is described in Fleeman (2007).

Once the telephone number was determined to be eligible for the pilot study, one adult within the household was selected using the modified Rizzo method as described in Section 2. This differed from the prior cell phone research that did not use any respondent selection methods and instead interviewed the adult who answered the telephone.

In the CHIS 2005 cell phone pilot, approximately 70 percent of cell-only households had more than one adult. However, only 11 percent of cell-only households with more than one adult shared the cell phone. In shared cell-only households the screener respondent was selected half of the time. Overall, the screener respondent was sampled for the extended interview 96 percent of the time.

Unlike the landline sample, where adults, children, and adolescents were eligible for the study, only adults were sampled in the 2005 cell phone pilot. The interviews were only conducted in English and a total of 99 respondents completed the extended interview. The overall response for the cell phone pilot was 16.3 percent, which was about 10 percentage points lower than overall adult response rate in CHIS 2005.

At the time of the pilot sample, effective weighting methods of cell phone samples were not fully developed. These weighting methods did not address the observed differential response by telephone status and usage found in previous cell phone surveys (Brick et al., 2007) that caused severe nonresponse bias in estimates of telephone status. In addition, estimates correlated with telephone usage might have been also biased. In order to mitigate the effect of bias, the screener interviews that were not eligible for the extended interviews because of telephone usage were include as part of the weighting process.

The objective in creating weights for the pilot sample was to produce estimates for the entire adult population. To do this the pilot sample was considered as a supplement to the

landline RDD survey. In the first step of weighting the pilot sample, a base weight was computed as the inverse of the probability of selection of the telephone number in the cell phone frame. Ported cases from the landline sample had their base weight created in the same way as the landline sample. In the next step, the base weights were adjusted for nonresponse. Unlike the landline that was adjusted using nonresponse cells based on geography, the pilot sample was adjusted by the inverse of the nonresponse rate without the use of any auxiliary data.

In the next step, the weights were adjusted to account for multiple changes of selection for the cases where the cell phone was shared. In the last step, the landline and pilot samples were combined and raked using the same control totals used in CHIS 2005. In this approach, the cell-only sample accounted for 8.7 percent of all adults in spite of the estimate that 10 percent or more of adults were cell-only. The weights of the cell phone sample were in average 40 times larger than those in the landline sample and were the result of the disproportional allocation between the samples. As a result, there was an increase of the estimate of variance by a factor of nearly two. These results highlighted the importance of the allocation between the landline and cell phone samples.

5. CHIS 2007

Based on the results of the CHIS 2005 cell pilot study, a supplement cell sample was implemented in CHIS 2007. The goal was to complete 800 interviews with adults in California that lived in cell-only households. Whereas the 2005 pilot was a feasibility study and had limited goals, the 2007 cell sample was designed to incorporate both geographic targets and to be a supplement to the landline component of CHIS. This required the production of weights.

Since county-level geographic data was not available for the sample of dedicated cell phone banks, the geographic sampling strata were created in an indirect way. Using data from previous CHIS surveys, we determined the coverage of counties for each of the California area codes. Although some area codes were completely contained in a single county, most area codes covered multiple counties. Counties with the greatest proportion of households in an area code were assigned to that area code. Counties were then assigned to one of 7 geographic regions in California.

When determining the sample size to draw in each region, it was assumed that proportions of cell-only household and response rates were constant across regions. In 3 regions the sampling rates were increased to yield a minimum of 60 interviews in each of these regions. The other four regions were assigned the same sampling rate. Although the sampling rate assignment was done at the region level, the sample was selected using area code as the sampling stratum.

Data collection methods for the cell phone sample were similar to those for the CHIS 2007 landline component with a few important differences. As mentioned before, no prenotification letters were sent for the cell phone sample but cell sample respondents were offered $5 to complete the screener and $25 for the adult extended interview. All sampled numbers were eligible for screener refusal conversion; however, unlike the landline sample, conversion was not attempted for second refusals at the screener level. Furthermore, there was no conversion attempted for refusals of the adult interview. In CHIS 2007, there were no child or adolescent extended interviews. The procedures for the sampling of adults within the cell-only households were the same as those used in the

CHIS 2005 cell pilot study. Since only cell-only households were eligible, the cell phone frame and the landline frame did not overlap and they each represented separate populations.

The survey completed 825 extended interviews in cell-only households. The overall response rate was 15.9 percent, which was slightly lower than the rate for the 2005 pilot and approximately 4 percent lower than observed for adults in the CHIS 2007 landline sample. Regionally, the lowest response rate for the cell sample was 13.3 percent and the highest regional rate was 22.6 percent.

As in the pilot sample, the cell phone sample for CHIS 2007 was screened for cell-only households. This screening process implicitly created two non-overlapping sampling strata. The first stratum included households with only a cell phone, and the second stratum included households with both a landline and a cell phone. Households in the second stratum were not eligible for the extended interview. Thus, there was no need to compute the multiple probability of selection for households in this stratum. Cell-only households classified into the first stratum had only one chance to be selected in the sample, so their base weights were computed as the inverse of the probability of selection from the cell phone frame.

In creating the base weight for cell-only households the process began by creating the base weight for the cell sample. For the telephone numbers that were ported from landlines, the base weight was the landline base weight based on their landline strata. For the sample that came from cell sample, their base weight was computed as

$$CPBW_{hi} = \frac{NC_h}{n_h},$$

where n_h is the total sampled numbers in stratum *h*, and NC_h is the total numbers in stratum *h*, computed as $NC_h = 1000 \cdot NS_h$ where NS_h is the number of 1,000 blocks in stratum *h*.

The cell phone base weights were then adjusted for unknown residential status, unknown eligibility and nonresponse, and then the weights were benchmarked to the estimated proportion of cell-only households in California. In the cell sample, the weighted proportion of screener interviews reported as cell-only households prior to this adjustment was 39 percent. The estimate used for cell-phone-only households, among households that have cell phones, was 18 percent. This figure was based on the estimates of the West region over the last 6 months of 2007, as reported in the National Health Interview Survey (NHIS) (Blumberg and Luke, 2008).

One likely reason for the difference in the estimate from CHIS and the benchmarked NHIS estimate was due to the differential response rate of cell phone users; cell-only users were much more likely to answer their cell phone than less-frequent cell phone users. After benchmarking to NHIS estimates, this sample was combined with the final CHIS 2007 landline/list sample and the combined CHIS samples were poststratified to person-level control totals for the state of California.

6. CHIS 2009

The CHIS 2009 cell phone sample had a state-wide target of completing 1,100 interviews with adults living in cell phone-only households. In 2009, unlike the 2005 and 2007 cell samples, interviews were attempted with all cell phone respondents including those that had a landline. Thus, it was an overlapping dual frame approach.

In order to reach the goal of 1,100 cell-only households, we expected to complete 1,420 adult interviews from adults with both types of telephone services (landline and a cell phone). Additionally, in contrast with CHIS 2005 and 2007, children and adolescents were also selected from the cell phone sample. All other data collection methods for the CHIS 2009 cell phone sample were similar to those used in CHIS 2007.

When determining the sample size to draw for the CHIS 2009 cell sample, we used the observed response rates and proportion of cell-only households within regions from the cell sample in CHIS 2007. Furthermore, the misclassification rate between the sampled region and the self-reported region observed in the 2007 study was incorporated into the sample design. The sample was then allocated across regions and area codes so that the expected number of completed cell phone interviews would be the same across the 7 regions, and yield a total of 1,100 adult cell-only interviews.

A total of 3,047 extended adult interviews were completed from the CHIS 2009 cell sample; 1,187 of these were with cell-only households and 1,860 were from households with both a landline and cell phone. Additionally, 593 interviews about children (201 in cell-only households), and 197 adolescent interviews (52 in cell-only households) were also completed using the cell phone sample. The overall adult response rate was 10.7 percent which was lower than the comparable 2005 and 2007 rates and approximately 7 percent lower than what was observed for adults in the CHIS 2009 RDD landline/list sample. Regionally the response rates were fairly consistent with a low of 10.4 percent while the highest regional rate was 12.8 percent.

The cell phone sample for CHIS 2009 included those households with and without a landline telephone. Using the overlap sampling method created two strata. The first stratum included households with only a cell phone, and the second stratum included sampled households with both a landline and a cell phone. Cell-only households that were classified into the first stratum had only one chance to be selected in the sample, and their base weights were computed as the inverse of the probability of selection. Households in the second stratum were also eligible for the landline RDD survey. Thus, there is the need to account for their multiple probabilities of selection. We used a composite factor to do this.

The creation of the CHIS 2009 cell sample base weights used the same approach as in 2007. The cell phone base weights were then adjusted for unknown residential status and nonresponse at the household and person levels. Before creating the composite weights, both samples were poststratified separately to control totals defined by telephone status (i.e., persons in landline only households, persons in cell phone only households, and persons in households with both services). The distribution of telephone status for California was derived from the National Health Interview Survey for January to June 2010 for the West region.

Once the samples were poststratified, a composite weight that combined the landline and

cell phone sample was created. Based on research by Brick et al. (2011), the composite factor $\lambda = 0.9$ was used to reduce the bias of estimates computed from the combined sample. This factor and its complement $(1-\lambda)$ can be seen as additional weighting adjustment factors to apply to the poststratified weights. The expression of the composite weight, $cwgt_j$, is

$$cwgt_j = \begin{cases} pwgt_j & \text{If person } j \text{ lives in a household with cell only or landline only} \\ \lambda * pwgt_j & \text{If person } j \text{ lives in a household with cell and landline from the landline sample} \\ (1-\lambda) * pwgt_j & \text{If person } j \text{ lives in a household with cell and landline from the cell sample} \end{cases}$$

where $pwgt_j$ is the poststratified person weight.

7. CHIS 2011

In 2011, CHIS was redesigned as an ongoing study with a rolling sample where data are collected over a two year period with yearly milestones. The first two-year cycle of data collection is currently in progress but preliminary weights have been produced to meet the yearly milestones.

This design is considered a fully integrated design because the cell and landline samples are no longer considered separate entities. In 2009 and prior cycles, there were separate quotas for the cell phone and landline samples. Beginning in 2011, county level targets are set for the combined landline and cell interviews. Additionally, the cell sample for 2011 is significantly larger than in prior cycles, with a goal of 8,000 interviews over the two years.

In order to meet the goals on CHIS 2011, geographic targeting was expanded to 28 sample strata based on counties or groups of counties. The cell phone sample design cannot be targeted as precisely as the landline sample's 44 strata. However, the 28 strata is a vast increase over the seven regions targeted previously. Data from the cell interviews in previous CHIS cycles were aggregated to aid in the expanded geographic targeting. As more cell phone data are collected, geographic targeting should become more precise.

As in 2009, the CHIS 2011 sample design is an overlapping dual frame design. Weighting will be done with the same procedures used in 2009 and composite factors will be used to combine the samples. However, after the two years when the full sample have been completed, it is expected the composite and trimming factors will be significantly smaller than those used in 2009 because of the much larger cell sample.

8. Conclusions and Further Research

Incorporating cell phones into the CHIS sample design has been an evolving process which is not yet complete. There are plans to continue improving the design. As the number of households that are cell-only is continually increasing, the allocation between

cell phone and landline samples will need to be revisited. The amount of the sample allocated to cell phones should increase over time. However, as cell phone sampling is more expensive than landline sampling, increasing the proportion of the sample allocated to cell phones will increase the survey costs.

In addition, the sampling vendor has recently released a new product for cell phone samples that attaches zip codes and an indicator of whether or not the phone number is a working number to each sampled number. The accuracy and usefulness of this additional data need to be tested to determine if the data would be beneficial to CHIS in geographic targeting and increasing sample yields.

As more cell phone cases are fielded, more data will be available for aggregation. This will aid in geographic targeting. More data will allow for finer divisions of strata, striving to match that of the landline sample. Additionally, more data will allow for a better understanding of the misclassification rates associated with assigning numbers to strata based on area codes.

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