Assessing the Use of a Pre-Field Screening Service to Identify Nonworking Cellphone Numbers in Ohio

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Abstract
In recent years, most RDD telephone surveys have introduced a cellphone frame to augment the landline sample to improve coverage and reduce variance. However, due to a number of challenges including the restrictions in how cellphone numbers can be dialed it can be more expensive to complete cellphone interviews and often for this reason the proportion of the total sample allocated to the cell phone frame has been kept artificially small (e.g., 25% of the sample) to reduce data collection costs. As more people shift away from using land lines it becomes increasingly important to increase the allocation of RDD sample to the cellphone frame. For example, in the state of Ohio, in 2012, 52.6% of persons were cellphone only or cellphone mostly users (Blumberg, et. al., 2013). These persons also tend to be younger, more likely to have children, and minority (Lu, et. al., 2014). Sample vendors are increasing the information attached to cellphone telephone numbers to help improve performance and in this paper we investigate the effectiveness of the Cell-Wins service provided by Marketing Systems Group (MSG) which flags cellphone numbers that are actively being used by a person at the time the flag is applied. If accurate, this flag could greatly reduce data collection costs by identifying nonworking numbers prior to data collection. This paper presents an assessment of this flag in the State of Ohio conducted for the 2015 Ohio Medicaid Assessment Survey. We also determine the cost efficiency associated with excluding telephone numbers identified as inactive. We found that the accuracy of the Cell-Wins flag was high for telephone numbers identified as inactive and only introduced an under coverage rate of 2.4%. Furthermore, we determined that utilizing the Cell-Wins flag was cost efficient decreasing data collection costs a net 12%.

Key Words: Cellphone, Cell-Wins, coverage error, telephone survey, dual-frame design

1. Introduction

1.1 Background

With the decrease in the use of landline numbers among young persons and minorities and the increase use of cellphones by these populations (Blumberg, et. al., 2013; Lu, et. al.,

2014) dual-frame designs that utilize both the landline and cellphone frames are essential. However, cellphones must be dialed manually, which increases the cost of completing cellphone interviews. Until recently, most dual-frame surveys allocated a small proportion of the total sample to the cellphone frame in order to minimize costs while ensuring full coverage of the target population (see e.g., 2012 Ohio Medicaid Assessment Survey (OMAS), 2011-2012 California Health Interview Survey (CHIS)). Yet, as key demographic groups shift more to cellphone only use the need to increase the allocation to the cellphone frame has become essential (Peytchev & Neely 2013; Lu, et. al., 2014). For example, in the state of Ohio, 52.9% of adults and 62.8% of children live in cellphone only or cellphone mostly households (Blumberg, et. al., 2013). These percentages increase to 72.9% of adults and 85.6% of children when dual-user households are included. In designs that optimized cost and, thereby, minimized the use of cellphone respondents, the increase in the cellphone population has led to decreased precision due to an increased design effect (Peytchev & Neely, 2013).

With surveys increasing the proportion of interviews coming from the cellphone frame, the sample vendors – Market Systems Group (MSG) and Survey Sampling International (SSI) – have developed pre-field screening services to identify cellphone numbers that are active at the time the sample is drawn. For example, MSG has developed Cell-Wins which classifies a cellphone number as active (i.e., currently a number being used), inactive (i.e., a nonworking number), or unknown activity status (i.e., had previously been identified as working, but no activity has been observed in the past few months) (Dutwin & Malarek, 2014). The Cell-Wins activity flag is based on a proprietary algorithm developed by MSG which examines billing and usage data to determine the status of the number. Similarly, SSI has developed the *Wireless Phone Activity Flag*. Like Cell-Wins, this flag assigns cell-phones into three categories: active, previously active, and inactive/unassigned. In this paper, we focus on the accuracy of the MSG Cell-Wins status flag.

1.2 Motivation

Screening landline numbers to determine whether the number is assigned and working has been done for years and relies on automated dialing equipment and telephone contact signal processing. This approach is not available for cellphone screening because of limitations in the Telephone Consumer Protection Act of 1991. While new activity flags based on billing and usage data hold promise to mimic the screening process used on the landline frame, they have not been fully vetted and the consistency across geographic areas, even with a single state, is not fully known. Because cellphone numbers are sampled at the 1,000-block level many of them are invalid – nonworking or otherwise inactive telephone numbers. Including these invalid telephone numbers can greatly increase data collection costs since each cellphone number needs to be manually dialed. In terms of the population of interest, including the invalid telephone numbers greatly increases the sampling population, but the level to which it better covers the target population is less clear. ***Figure 1*** illustrates the potential relationship between the vendor activity flags (e.g., Cell-Wins) and the actual status of a telephone number (valid or invalid) in the sampling population. The figure shows how a large portion of the target population consists of invalid numbers.

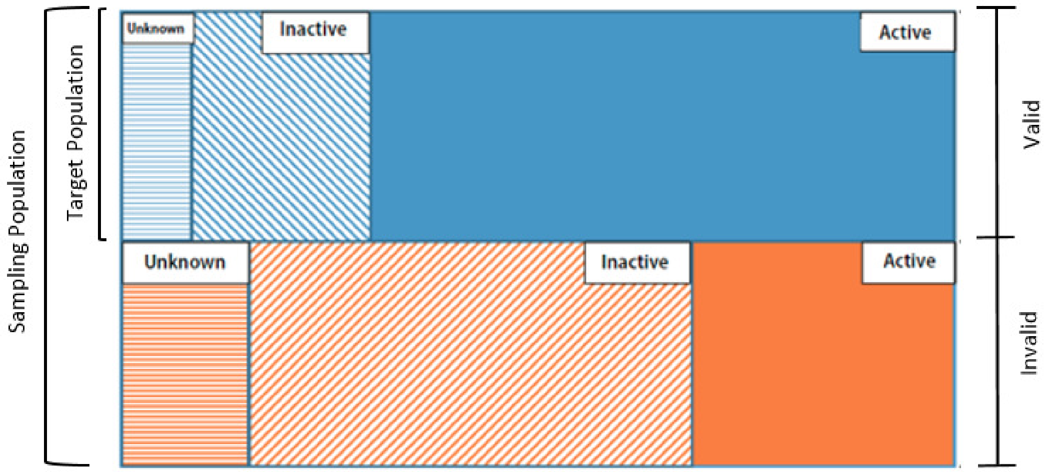

Figure 1: Target and sample population for sample of cellphone numbers by Cell-Wins activity status

If the Cell-Wins status accurately identifies invalid cellphone numbers (i.e., invalid and inactive in ***Figure 1***) then; (1) data collection costs can be greatly reduced by excluding Cell-Wins inactive numbers, and (2) the sampling population consisting of telephone numbers identified as Cell-Wins active or unknown status will accurately identify the target population because all active numbers are included in the sampling population. However, if Cell-Wins method for identifying invalid numbers is not accurate its use may cause serious coverage and bias issues.

1.3 Study Purpose

In this paper, we have two main goals:

1. Assess the accuracy of the MSG Cell-Wins flag in the state of Ohio
2. Determine the cost efficiency of the flag whereby assessing if the cost of purchasing the flag is worth the loss in coverage

In order to achieve these goals two primary research questions will be answered. Namely,

1. How accurate is the Cell-Wins flag?
2. What is the cost savings due to excluding inactive numbers?

For the first research question, we will break it down into three components: (1) the amount of under coverage incurred due to excluding telephone numbers identified as inactive, (2) the amount of over coverage incurred among telephone number identified as active, and (3) the amount of variation in the under coverage rate by geographic area. For the second research question, we will develop a cost-efficiency model to determine if the cost of purchasing the Cell-Wins assignment outweighs the field costs of calling telephone numbers assigned as inactive.

2. Methods

2.1 Experimental Design

In order to assess the MSG Cell-Wins flag an experiment was incorporated into the 2015 Ohio Medicaid Assessment Survey (OMAS). OMAS is a periodic survey of residents in the state of Ohio measuring the rate of health insurance coverage among adults and children and access that each have to medical services. Because these outcomes of interest vary across the state, it is important that any method introduced to reduce data collection costs does not disproportionately impact one part of the state more than another. Moreover, due to the increased cellphone use of minorities and poorer residents (Lu, et. al., 2014), the 2015 OMAS was designed to achieve 55% - 60% of its completed interviews from the cellphone frame.

Under the experiment, a random sample of 372 cellphone main sample replicates (approximately 18,500 telephone numbers) were selected. Because OMAS is interested in county as well as state estimates, the full cellphone sample was stratified by county using *County Rate Center*. County Rate Center identifies the billing center in which the telephone number was activated. While not a perfect measure for county, rate centers are highly correlated with where the user of the cellphone lives (Berzofsky, et. al., 2015). Due to the disproportionate number of main sample replicates in more urban counties, the experiment sample was stratified by *county type*. County type is a county classification that classifies a county as predominantly metropolitan, suburban, rural non-Appalachian, or rural Appalachian. Because county type is based on the population density within the county, the counties within the same county type are not necessarily contiguous. The replicates were allocated in a balance manner across the four county types. ***Figure 2*** presents the distribution of the replicates across the 88 counties in Ohio. In all 75 of the 88 counties had at least one replicate (approximately 50 cellphone numbers) in the experiment.

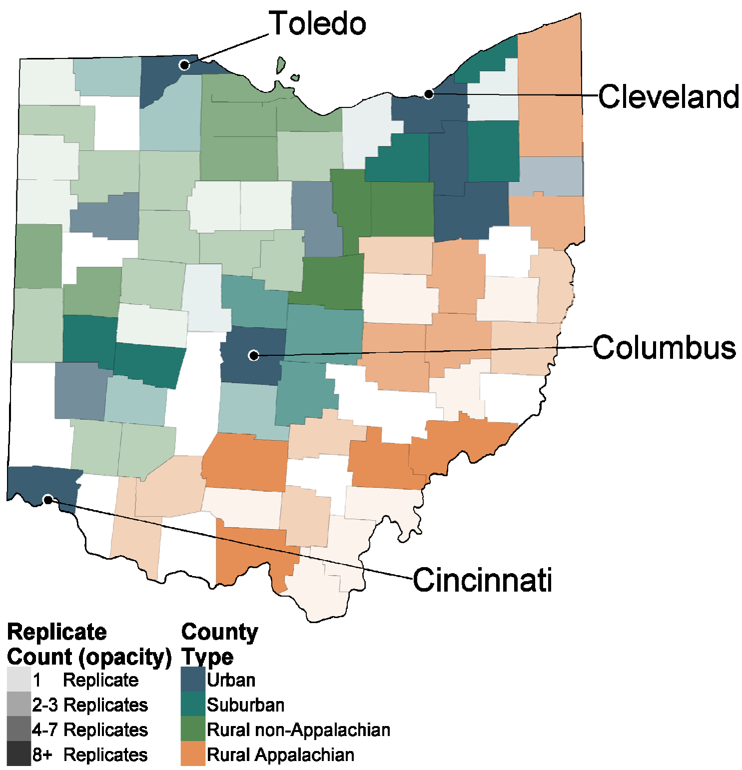

Figure 2: Distribution of Cell-Wins experiment replicates by rate center county and county type in the 2015 Ohio Medicaid Assessment Survey

Once selected, the telephone numbers from the replicates included in the experiment were sent to MSG to have their Cell-Wins flag assigned. This assignment was made as close to the start of data collection as possible in order to ensure maximum accuracy of the Cell-Wins assignment. ***Figure 3*** presents the activity status of the sampled numbers by county type. ***Figure 4*** presents the activity status of the sampled numbers by Medicaid region. Medicaid region is a set of contiguous counties within the state. There are seven Medicaid regions in the state. As the figures illustrate, the percentage of number assigned to each Cell-Wins classification varies across area type. For example, by county type, as seen in Figure 3, the range of telephone numbers assigned as inactive is 24.8% (rural Appalachian) to 36.6% (suburban). The range across Medicaid Region is not as wide as county type going from 27.2% in the Northwest to 33.3% in the Southeast.

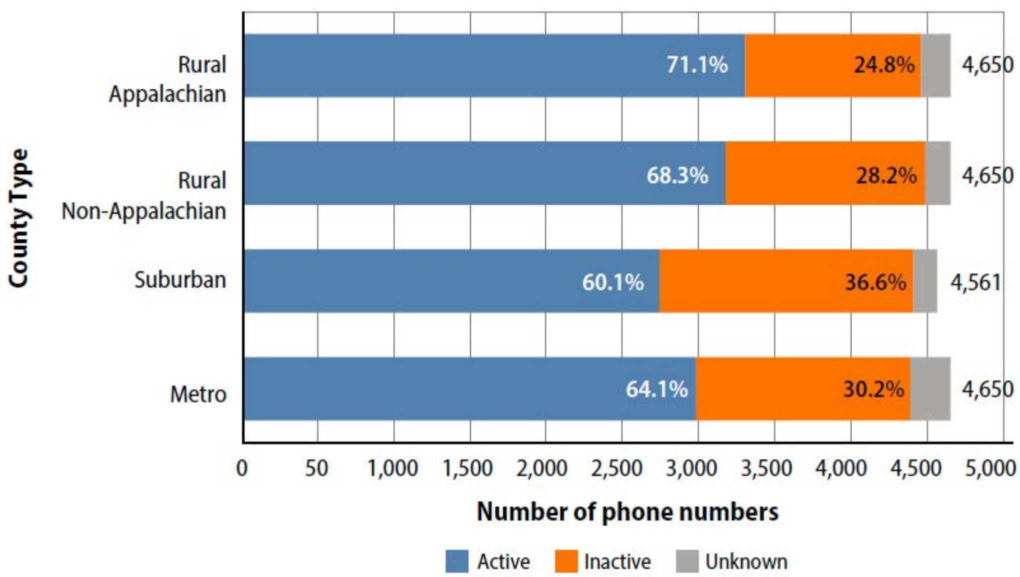

Figure 3: Distribution of Cell-Wins activity status by county type

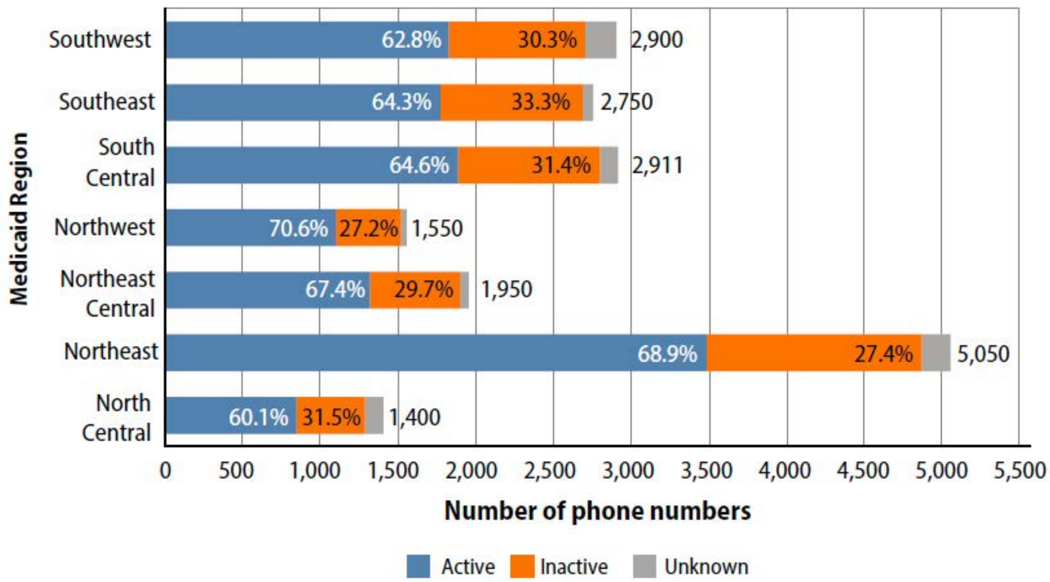

Figure 4: Distribution of Cell-Wins activity status by Medicaid region

Once the Cell-Wins status was assigned to each number, all telephone numbers, regardless of activity status, were released to the field. Each replicate was fully worked to completion. This included at least five call attempts to each telephone number (unless the disposition was finalized sooner). The field period for the experiment replicates went from December 2014 – February 2015.

Once finalized the final disposition status of each number was categorized into *valid* or *nonworking/invalid*. Valid numbers included any number that connected to a person regardless of response status. Nonworking or invalid numbers included any number that appeared to be nonworking including ring-no-answer telephone numbers and disconnected numbers.

2.2 Analysis Methods

2.2.1 Assessing Accuracy

To assess accuracy of the Cell-Wins flag assignment the cross-classification of the Cell-Wins assignment and the final disposition assignment was compared. Within each Cell-Wins type (active, inactive, and unknown), the number of valid and non-working/invalid numbers was determined using the final disposition obtained during data collection. Using these counts, the inaccuracy rate (IR) was determined for each Cell-Wins type using the formula:

$$IR_j = \frac{N_I}{N_C + N_I}$$

for $j = i$, a, or u representing inactive, active, and unknown, respectively; where N_I is the number of telephone numbers incorrectly assigned (e.g., Cell-Wins assignment as inactive, but with a final disposition of valid) and N_C is the number of telephone numbers correctly assigned. For Cell-Wins inactive numbers the IR_i represents the proportion of Cell-Wins assigned inactive numbers that are valid (i.e., a part of the target population). For Cell-

Wins active numbers the IR_a and IR_u represents the proportion of Cell-Wins assigned active and unknown telephone numbers, respectively, that are invalid (i.e., a part of the sampling population, but not a part of the target population).

The under coverage rate (UCR) due to excluding Cell-Wins inactive telephone numbers and over coverage rate (OCR) due to the inaccuracy of Cell-Wins active numbers (excluding the Cell-Wins inactive numbers) were then calculated using the IR for inactive numbers using the formulas:

$$UCR = \frac{N_i \times IR_i}{N_i \times IR_i + N_a \times (1 - IR_a) + N_u \times (1 - IR_u)}$$

and

$$OCR = \frac{N_a \times IR_a + N_u \times IR_u}{N_a + N_u}$$

To determine whether the under coverage rate varied by geographic area, the under coverage rates were calculated by county type and Medicaid region. Bivariate tests (i.e., t-tests) were conducted to determine if the under coverage rate due to excluding inactive numbers varied by geographic area within the state of Ohio.

2.2.2 Cost Efficiency

To determine the cost efficiency of excluding Cell-Wins inactive telephone numbers, a cost efficiency model was developed taking into account the cost of purchasing the Cell-Wins status flags and the cost of calling inactive assigned telephone numbers. The cost efficiency model was defined as:

$$CE_{CW} = \frac{C_{CW}}{DC_T} + \frac{DC_{T-I} - DC_T}{DC_T}$$

Where CE_{CW} is the net percent cost efficiency of removing the Cell-Wins inactive telephone numbers relative to total data collection costs, C_{CW} is the cost of purchasing the Cell-Wins status flag for all sampled telephone numbers, DC_T is the total data collection cost when all telephone numbers including the inactive assigned numbers are fielded, and DC_{T-I} is the data collection costs when the Cell-Wins assigned inactive cases are excluded (i.e., as if not fielded). Under this formula, when CE_{CW} is a negative percentage then excluding the Cell-Wins assigned inactive numbers increases the cost efficiency (i.e., the data collection costs saved due to call fewer telephone numbers outweighs the cost of purchasing the flag assignments) of the study while a positive percentage decreases the cost efficiency (i.e., the cost of the purchasing the flag outweighs the gains by calling fewer telephone numbers).

3. Results

3.1 Accuracy of Cell-Wins Flag

3.1.1 Assessing Overall Accuracy

To access the overall accuracy of the Cell-Wins flag, the Cell-Wins activity status was compared to the final disposition in order to examine any inconsistencies between the two assignments. ***Figure*** **5** presents the final disposition status by Cell-Wins assignment. Overall, the large majority of numbers flagged as inactive by Cell-Wins were truly non-working or invalid numbers with an inaccuracy rate of 3.7%. However, 32.3% of Cell-Wins assigned active numbers were deemed to have a non-working or invalid final disposition. While Cell-Wins unknown made up a small proportion of the sampled numbers, they predominately ended up being non-working or invalid numbers with an inaccuracy rate of 96.4%.

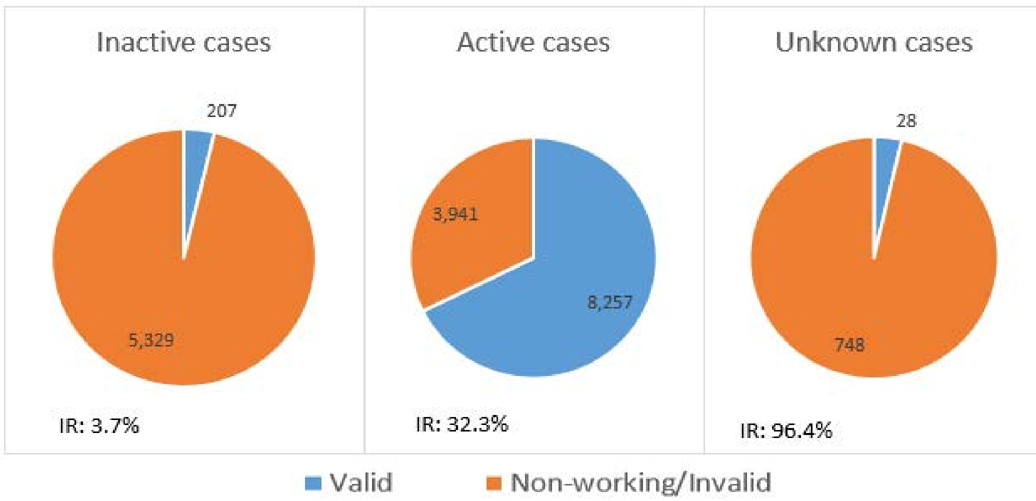

Figure 5: Actual activity status by Cell-Wins assigned activity status

3.1.2 Coverage Rates

The amount of under coverage incurred as a result of excluding telephone numbers identified as inactive was determined to be minimal with an overall rate of 2.4%. This finding is in-line with the findings of Dutwin and Malarek (2014) which found an under coverage rate between 5% and 6% nationally. Conversely, the amount of over coverage incurred among telephone numbers identified as active was 36.1%.

The under coverage rates were further examined by county type and Medicaid region in order to assess the consistency in the level of the accuracy of the Cell-Wins flag. ***Figure 6*** presents the under coverage rate when telephone numbers flagged inactive by Cell-Wins are excluded by county type. The largest amount of under coverage incurred due to the exclusion occurred in rural Appalachian with an under coverage rate or 3.7%. This under coverage rate was statistically significantly different from all other county types (metro, rural Non-Appalachian, suburban) at the 95% confidence level. This finding is consistent with the finding that a significant number of rural Appalachian cellphone users utilize a prepaid plan (Berzofsky, et. al., in press). Therefore, it is possible that Cell-Wins is not changing the status of newly activated prepaid telephone numbers at the same rate new telephone numbers are being activated. ***Figure 7*** presents the under coverage rates by Medicaid region. North Central had the highest level of under coverage with a rate of 3.4% whereas the Northeast had the lowest with a rate of 1.8%. There was a significant difference in the under coverage rates of the Northeast and South Central at the 95% confidence level.

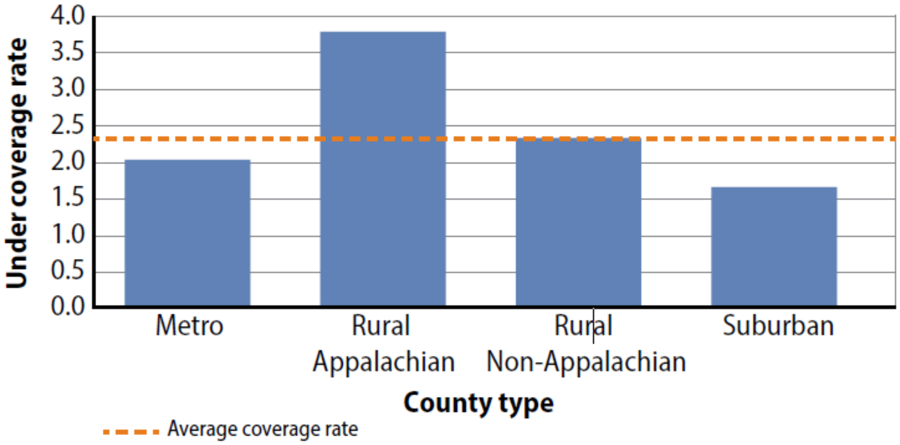

Figure 6: Population under coverage rate when Cell-Wins inactive numbers excluded, by county type

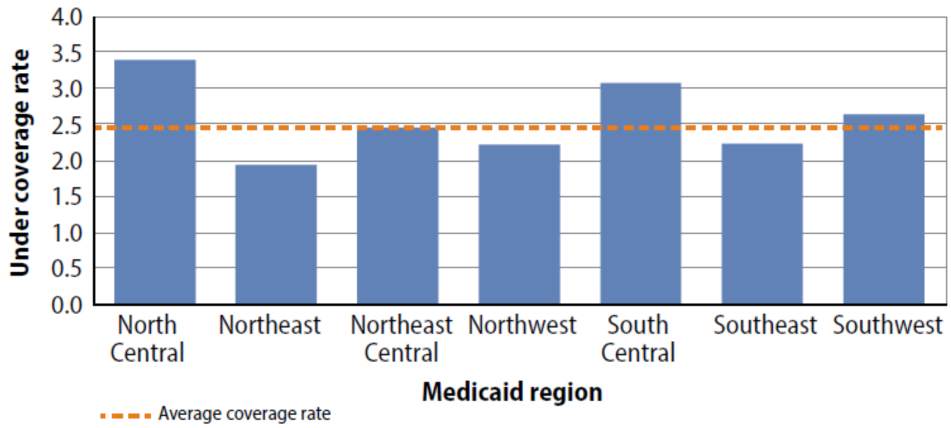

Figure 7: Population under coverage rate when Cell-Wins inactive numbers are excluded, by Medicaid region

3.2 Cost Efficiency

Among the experiment replicates, 108,000 call attempts were made. Of those call attempts, 15,009 were made to numbers flagged as inactive by Cell-Wins. Had these inactive cases been removed prior to data collection, the number of call attempts would decrease by 13.9%. However, there was an additional 1.9% increase in the cost of data collection in order to obtain the Cell-Wins activity flag. Using the cost efficiency model presented in ***Section 2.2.2***, the percent cost efficiency was determined to be -12%, indicating removing the inactive cases prior to data collection reduces the data collection cost by 12%. This finding is less than the 20% reduction in data collection costs that Dutwin and Malarek (2014) found.

$$CE_{CW} = 1.9\% + (-13.9\%) = -12\%$$

4. Conclusions and Recommendations

After addressing our research questions, we attempted to compare the demographic characteristics of respondents with a Cell-Wins inactive status to respondents with a Cell-Wins active status to determine if there were any differences. While there did not appear to be any, the sample size of respondents among numbers assigned as Cell-Wins inactive was too small to make credible statistical comparisons (the percentage of Cell-Wins inactive status numbers that led to a completed interview was only 4.2%). Therefore, in the absence of any differences in the respondent characteristics, based on the results of our experiment, the trade-off of an overall under coverage rate of 2.4% for an increased efficiency of 12% was deemed acceptable.

Thus, it was decided to exclude Cell-Wins inactive numbers from the reminder of cellphone replicates released in the 2015 OMAS. For our target population of 24,000 cellphone interviews, this translated into removing 179,000 sampled cellphone numbers prior to fielding (37.5% of all cellphone numbers released). Furthermore, while not implemented in the 2015 OMAS, our results indicate that telephone numbers assigned a Cell-Wins status of "unknown" are more like "inactive" telephone numbers than "active" numbers. Therefore, for the state of Ohio, in future studies, we suggest excluding Cell-Wins unknown telephone numbers as well as inactive telephone numbers. Alternatively, if excluding all Cell-Wins unknown telephone numbers is not acceptable, one could subsample unknown numbers to reduce the number fielded. However, this approach can be problematic if any of the unknown telephone numbers yield a completed interview because the resulting weights would be disproportionately larger due to accounting for the telephone numbers that were subsampled out.

While we believe that the Cell-Wins flag proved accurate enough for Ohio, it is important to note that, just as the flag accuracy varied within Ohio, it could vary in different parts of the county. Therefore, we recommend a similar type of experiment be conducted the geographic area of interest prior to excluding Cell-Wins assigned inactive telephone numbers. Furthermore, additional research could be conducted to determine if the characteristics of persons with a Cell-Wins inactive assigned telephone number are different from persons with a Cell-Wins active assigned telephone number.

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