The Cell Phone Universe: Methodological Considerations for Creating Cellular and Landline Telephone Estimates from Nielsen Television Surveys

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Abstract

The proliferation of cellular telephones in recent years has presented a challenge for public opinion researchers, particularly in regards to coverage error in random digit dial (RDD) data collection and telephone frame sampling techniques that are increasingly unable to reach households that use cell phones exclusively. This challenge has established a need for current estimates of cell phone only households to evaluate potential biases resulting from undercoverage, in addition to sample weighting and recruitment. To date, estimates of cell phone only households have largely been available only periodically and for capacious geographies. Given that an increasing number of households are becoming cell phone only, and large-area estimates are of limited utility for many applications, there is a need for household telephone status estimates available in a timely manner for smaller geographic areas based upon contemporary data. To address this need within The Nielsen Company, the Media-demography group is conducting evaluation research on the possibility of creating quarterly estimates of households by cellular/landline telephone status. This paper provides a brief overview of the media-related universe estimation methodology applied to cell phone estimation from Nielsen television panels and surveys, discusses limitations and advantages in applying this methodology to estimates of household telephone status, and provides preliminary data on these telephone household types using Nielsen television data. The results of this research will provide additional insight to the challenges of estimating households of varying telephone statuses and provide alternative and current information on the status of cell phone only adaptation in the U.S for national and sub-national geographies.

Key Words: Universe Estimates, Cell Phones, Weighting

1. The Wireless Effect and Nielsen Media Universe Estimation

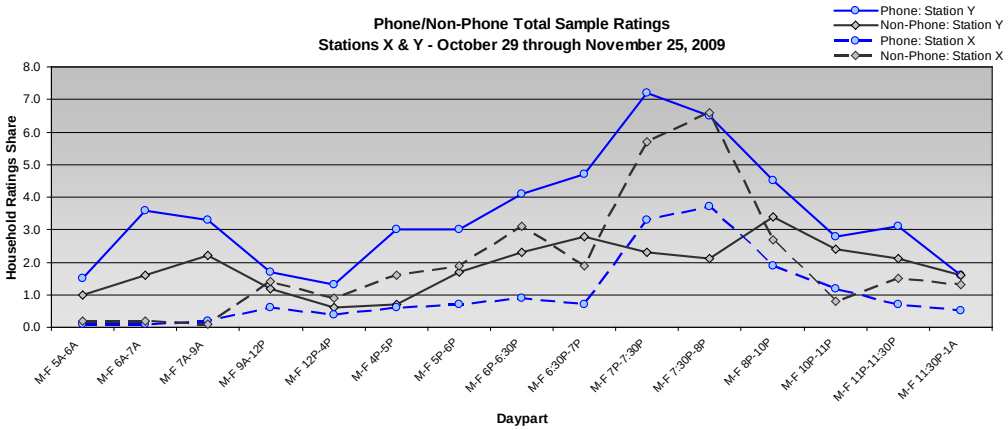
The proliferation of cellular telephones (also referred to as cell phones, mobile phones, or wireless phones) in recent years has presented a challenge for public opinion researchers, particularly in regards to coverage error in random digit dial (RDD) data collection and telephone frame sampling techniques that are increasingly unable to reach households that use cell phones as their exclusive telephone line. While landline telephone coverage has been above 90% since at least the 1980s, the number of households with landline telephones has diminished considerably in the past decade whereas households which have only cell phones have dramatically increased. Results from the National Health Interview Survey (NHIS) indicate that the percentage of households which are cell phone only (i.e. households where the only telephone is cellular-based as opposed to a wired

landline telephone) has increased from 7.3% in the first half of 2005 to 20.2% in the last half of 2008 (Blumberg and Luke 2009). The rampant growth of cell phone only households has readily threatened to outpace both empirical literature and available data to properly measure these classifications, though gains have been made in recent years. Measuring the impact of cell phone only households on survey research is thus something of a "moving target;" one which is increasingly difficult to dimension given available data and analyses.

The prospect of bias resulting from omitting cell phone only households from a sampling universe has not been a salient one until recent years given the aforementioned growth in cell phone only households. While excluding cell phone only households from the sampling frame only presents bias if respondents in cell phone only households differ from respondents not in cell phone only households (Groves et. al. 2009), several studies have shown that respondents in cell phone only households tend to be predominately unrelated renters, of lower income, younger, predominately Hispanic or belonging to other non-white racial/ethnic groups, and unmarried (Blumberg and Luke 2008, Blumberg et. al. 2008, Tucker et. al. 2007, among others). Thus, neglecting cell phone only households from a sampling universe leaves open the possibility for non-negligible bias (Blumberg and Luke 2007). While there is evidence weighting can account for a portion of this possible bias, demographic controls for these biases as they exist now have been largely insufficient (Link et. al. 2007).

This insufficiency is due in part to the considerable lag in relevant weights compared to the rapid pace of cell phone only adoption, though utilization of forecasting methods have been encouraging (Ehlen and Ehlen 2007). Ultimately, a key problem in current weights accounting for cell phone only populations is a lack of regular population standards. While the NHIS has provided critical information at the national and census regional level (most recently in Blumberg and Luke 2009)[1], the need for sub-national estimates has been long called for in evaluations of cell phone only households (Link et. al. 2007, AAPOR Cell Phone Task Force 2008). Beyond coverage considerations, the possibility of differentiations or biases in regards to substantive measures (specifically, television viewing for the evaluation here) across households of varying telephone statuses remains an item of consideration. As an example, an evaluation of viewing for a large south-eastern United States television market demonstrates distinct viewing differences in phone and non-phone households for Station X (a broadcast station usually attributed as having a younger and predominately non-white audience) and Station Y (a broadcast station usually attributed to having a older and predominately white audience).

[1] Recent state-level estimates have been created via statistical modeling (Blumberg et. al. 2009), and will be discussed in detail later herein



These results demonstrate that Station X clearly has a higher ratings share among non-phone households compared to phone households, whereas the opposite is true for Station Y. As such, it can be reasonably inferred that viewing behavior varies depending upon the phone status of the household due in part to the associated demographic and socioeconomic characteristics commonly associated with these types of households. The magnitude of these viewing differences implies that household phone status may be a potentially valuable weighting control for substantive measures. Heretofore, no up-to-date estimates of the phone status for households at sub-national geographies have been available as a basis for constructing universe estimates. To partially account for both the temporal lag and geographic limitations of available estimates of households by phone status, The Nielsen Company has conducted evaluation research on creating universe estimates of television households by phone status, on a quarterly basis, for sub-national geographies, using the Nielsen television panel and associated surveys.

The Nielsen Company produces the most widely utilized national and local television ratings. In the U.S. alone, television ratings direct upwards of $70 billion in advertising revenue, annually. TV ratings measurement is facilitated locally by either an ABS or area probability-selected household sample wherein viewing diaries (for less populous television markets) or electronic measurement devices installed on working televisions (for larger markets) are used to measure tuning activity. At a national level, the National People Meter (NPM) sample consists of an average of 20,000 households with electronic measurement devices installed on working televisions. A crucial technical component of television ratings calculations and reporting are Universe Estimates (UEs). UEs are a series of national and local demographic estimates for television households and persons therein. Broadly, UEs serve two primary purposes: First, UEs serve as controls for Nielsen samples during sample selection, recruitment, maintenance, evaluation, and weighting. Second, UEs are used as the denominator for ratings calculations, in addition to being provided to clients for informational and marketing purposes.

UEs are created not only for standard demographic and socioeconomic items (i.e. age, sex, race, income, education, etc.), but also households with particular configurations of media viewing technology such as households that receive television via cable or satellite. Estimates of media technology (media-related UEs) rely upon data from Nielsen panels or viewing diaries because reliable data from external sources do not exist, or are not updated frequently enough for timely estimation. Further, because media-related technologies tend to change quickly (or at least more quickly than other demographic items which are updated annually), these estimates are updated multiple times throughout the year to keep pace with the rapidly changing home media environment. The unique

data needs of the media-related estimates, in addition to the already regular updates of the estimates using a large sample of area probability or ABS selected panel and diary data, ideally positions the media-related methodology/system and associated data inputs to measure quickly changing U.S. telephone configurations.

After a brief overview of the media-related estimation methodology, the resultant estimates are compared against existing measures of households by phone status from the NHIS, where applicable. These estimates are among the first estimates of phone status calculated from a contemporary and robust data source for sub-state geographies that we are aware of. Thereafter, we examine results from statistical tests which are used to determine the feasibility of accurately measuring periodic estimates resulting from the media-related universe estimation methods. The results from these tests carry several implications for accurately measuring households by telephone statuses in the U.S. at sub-national geographies. Finally, we comment on the state of cell phone adoption in regards to coverage and weighting considerations as well as pressing concerns for accurate weighting and population projections for these household types.

2. Media Related Universe Estimation Methods

Media-related UEs are produced at the beginning of the TV season (typically as of September/October), in addition to updates prior to the TV "sweep" periods of February, May, July, and November. National UEs are based on the installed National People Meter sample which electronically collects viewing data directly from Nielsen panel homes. Meter data is also the basis of local (i.e. sub-national and market-level) UEs where available. Specifically, local meter data is available in television markets with larger populations and/or sufficient financial support[2]. Otherwise, local viewing is measured via viewing diaries sent to samples of households in less-populous television markets via ABS selection[3]. The sample data is weighted to a set of household characteristics that are correlated with household media-related statuses. Weighting is performed at each level of geography at which the UEs are produced: at the national, sub-national, and designated market area[4] (DMA) levels. The weighting controls used for media-related UEs are distinct from the weighting controls used for viewing estimates, and represent a broad array of demographic and socioeconomic information (i.e. age of the householder, presence of children, income, education, etc.).

Computation of National media related UEs typically utilizes four weeks (28 days) of meter sample data. After weighting has been performed at the national level, the sums of the household weights are aggregated for the various media-related characteristics. Projections (and thus the final UEs) are produced by applying the given media-related characteristic's penetration to the current National TV household universe estimate. The sample data is then cutback to sub-national areas to construct unreported sub-national estimates that are used as controls for DMA-level estimates. Typically, DMA level

[2] For purposes of brevity, we do not distinguish between different types of meters here.
[3] For metered markets which recently transitioned from telephone frame to area probability sampling, phone UEs are based on diary samples as the metered samples will still contain a fair number of homes selected using telephone frame sampling methodology which could bias the estimates.
[4] DMAs are collections of counties (or county parts) originally based on Metropolitan Statistical Areas which represent geographic areas that receive common local television programs, typically from a central city area.

estimates for metered television markets utilize four, non-continuous, four-week periods spread across the previous 6-10 months in a rolling average. Diary-measured television markets utilize a rolling average of four, non-continuous, four-week periods of diary sample. After weighting within each market for the period, the sums of the household weights are aggregated for the household phone characteristics and applied to the local TV household universe estimate for each market.

The four-period moving averages are used in the local media-related UE computations in order to increase the sample size and minimize sampling error. While this smoothing process increases the stability of the estimates, the resulting estimates may be too dated to reflect real changes in technology adoption trends. Many media-related characteristics are rapidly growing technologies, such as digital video recorders (DVRs) or high definition (HD) television sets. Despite the relative frequency of the updates, certain characteristics are growing so rapidly that Nielsen opts not to publish official UEs for these quickly changing characteristics. Before Nielsen will release an official UE for a particular media-related characteristic, a growth analysis is performed to determine eligibility for release. This analysis is a measure of how quickly a particular media-related characteristic is growing between measurement periods. As such, the results of the growth test indicate whether the UEs in question will be reliable for reporting and weighting purposes, or whether any "published" UEs will be essentially outdated by the time they are produced due to a possible lag between the sample characteristic data and the projected measurement date.

In some cases, Nielsen opts to report unofficial estimates for rapidly growing characteristics using a modified methodology. With this modified methodology, the moving average is not used and the local calculations are based only on the most recent period of weighted data. Due to concerns over sampling error estimates produced with this methodology are not eligible for use in weighting, selecting Nielsen samples, or reporting in syndicated products. This methodology was applied to the evaluation of potential phone status UEs that were computed for four types of household phone configurations: cell phone and landline households, cell phone only households, landline only households, and no phone households. Due to how quickly household phone statuses are shifting in the U.S., household phone status estimates are subject to the aforementioned growth analysis using data from Nielsen's installed TV meter panels. The first step in the growth analysis is to perform a test of statistical significance between two 28-day periods at the end of consecutive quarters for each of the fifty-plus meter panel markets. The formulas below are specially modified for measuring phone status households and use notation for "cell only" households though each phone status type is tested using these formulas. First, the percentage of cell phone households is created across all days and all households for each comparison period. In the case of the estimates calculated here September 2009 is period one, and December 2009 is period two:

$$ue_{cell,p} = \frac{\sum_{h=1}^{n}\left(\sum_{d=1}^{t} Ins_{h,d} * Cell_{h,d}\right)}{\sum_{h=1}^{n}\left(\sum_{d=1}^{t} Ins_{h,d}\right)}$$

Where r_{cell} is the proportion of cell phone households, *n* is the number of homes installed for one or more days for the period, *t* is the number of days installed during a given period, *p* is the number of the period (i.e. 1 = previous or 2 = current) and

- $Ins_{h,d}$ is the an indicator for whether the h^{th} household on the d^{th} day for period is installed in the sample (1) or not (0).
- $Cell_{h,d}$ is the indicator for a cell phone household (1) or not (0) of the h^{th} household on the d^{th} day.

Next, a difference in the proportions between the current and prior periods is computed. In order to test whether the difference is statistically significant, a standard error of the difference between the two periods is computed. The formula below takes into account the fact that this data is collected from a panel. As a result, some homes will be installed both periods, so therefore the samples are not independent. A delta for each home in both periods is created against the aggregated average penetration of cell phone households $(r_{cell,p})$ for the respective period:

$$\delta_{h,p} = \frac{\left[\left(\sum_{d=1}^{t} Ins_{h,d} * Cell_{h,d}\right) - \left(\left(ue_{cell,p}\right)\left(\sum_{d=1}^{t} Ins_{h,d}\right)\right)\right]}{\sum_{h=1}^{n}\left(\sum_{d=1}^{t} Ins_{h,d}\right)}$$

The delta values for each household in the previous period are subtracted from the current period, squared, and subsequently summed such that a total variance measure for the difference between the two periods is computed:

$$Var(ue_{cell,p=1-2}) = \left(\frac{n}{n-1}\right)\left(\sum_{h=1}^{n}(\delta_{h,p=1} - \delta_{h,p=2})^2\right)$$

This allows for standard error of the difference as a percentage to be calculated:

$$SE(ue_{cell,p=1-2} * 100) = 100 * \sqrt{Var(ue_{cell,p=1-2})}$$

The resulting standard error is used to perform a one-tailed significance test which determines whether there is statistically significant growth between periods. The growth analysis considers not only the statistical significance of the differences across markets, but also the size of the differences. A characteristic fails the test (i.e. considered to be rapidly growing) when 10% or more of the meter markets have p-values < .10 as well as relative differences that are greater than 5%. To be eligible, a characteristic must pass the test for three consecutive periods. In other words, if there is significant and sizable growth between periods a characteristic will "fail" and become ineligible to be an official universe estimate as there is little confidence that any reported estimate will be an accurate reflection of the characteristic for a given projection period due to how quickly the characteristic is growing in the metered TV panel.

The assumption of "growth" tends to be perfectly logical for new media-related UEs typically tested in this manner (i.e. households with DVRs or HD sets which are both

rapidly expanding). However, because certain aspects of phone status are theoretically growing (i.e. cell phone households, alone or in combination with a landline) while other are diminishing (i.e. landline only households), measuring only "growth" would provide an incomplete estimate of possible variation between periods for phone status UEs. Thus, the positive one-tailed "growth" test is supplemented with a negative one-tailed "decline" test and a two-tailed test measuring total "difference" around a particular phone status estimate.

In summary, two critical dimensions of phone status in the U.S. will be measured: Both absolute estimates of households by phone status that are highly contemporary and estimated for national, regional, and sub-national geographies, and a series of measures testing how quickly these discrete categories are shifting in the U.S. The former dimension allows for comparative analysis of what proportion of the U.S. falls into each of these categories, the latter provides implications in regards to the plausibility of accurate and up to date household phone status estimation. However, at least two limitations should be noted. First, the results here depend upon the Nielsen panels and diary data which can only be attributed to households with an operable television set that can receive at least one channel. Though this represents approximately 98.9%[5] of all households in the United States, this basic definitional discrepancy precludes the possibility of applying these findings to all U.S. households without this caveat. Second, some controls are implemented prior to the calculation of the UEs (i.e. they are not pure reflections of sample disposition), which leaves open the possibility that controls typically correlated to media-related technologies may not be as appropriate for estimates of telephone statuses. As such, some error may have potentially been introduced into the estimates at this preliminary, evaluation stage of estimation. Regardless of these limitations, the data here provides a useful and heretofore largely unexplored view of telephone adaptation in the U.S. and empirical measures as to how quickly the home telephone climate is changing.

3. Results and Discussion

Two sets of cell phone estimates were calculated: the first for the period of October 2009 and a second set for February 2010. The "October 2009" and "February 2010" dates correspond to Nielsen measurement periods for which the resulting estimates would have been used and not to the dates when the sample data were collected. Nielsen's media-related UEs, by necessity, must be completed prior to a measurement period thus the UEs will always be computed using data from before the measurement period. The October 2009 estimates use meter sample from early July to early August 2009, and the February 2010 estimates use meter sample from mid-December 2009 to mid-January 2010 and diary sample from the November 2009 measurement period. The first set of cell phone estimates for October 2009 represent the earliest period that phone estimates can be reliably calculated from Nielsen data given that the phone status of the household was not captured in the panel data until shortly before this period. Being the closest in terms of measurement period to the latest NHIS estimates, the October 2009 estimates will be used as the primary comparative data set (still, a highly considerable length of time separate the measurement periods of the two sets of estimates). The February 2010 estimates will be used as the primary reference for the current state of cell phone only

[5] This percentage was determined via an analysis of 1970 Census results (which include information on TV vs. non-TV households), the Residential Energy Consumption Survey, the Survey of Income and Program Participation, and data from the Nielsen panels.

adaptation in the U.S. In terms of comparisons, at the national level, key differences between the NHIS and Nielsen phone estimates are apparent. Table 1 demonstrates that while estimates of "Cell Only" are extremely close, most other statuses vary in direction.

Table 1: Comparison of October 2009 and February 2010 Nielsen Phone Status Penetrations Compared to July-December 2008 NHIS Results* for Total U.S.

	No Phone %	Landline Only %	Cell Only %	Cell and Landline %
NHIS July-December 2008	1.9	17.4	20.2	59.6
95% Confidence Interval	*(1.64, 2.18)*	*(16.22, 18.57)*	*(18.84, 21.69)*	*(57.96, 61.15)*
Nielsen Total TV HHs, Oct 2009**	0.9	12.4	20.0	66.6
95% Confidence Interval	*(0.72, 1.08)*	*(11.79,13.01)*	*(19.29, 20.71)*	*(65.82, 67.38)*
Nielsen Total TV HHs, Feb 2010***	0.6	10.2	21.3	67.8
95% Confidence Interval	*(0.47, 0.73)*	*(9.64,10.76)*	*(20.55,22.05)*	*(67.00, 68.60)*
Nielsen Hispanic TV HHs, Oct 2009**	2.0	10.9	28.0	59.1
Nielsen Hispanic TV HHs, Feb 2010***	0.9	8.4	32.7	57.9

**Blumberg SJ, Luke JV. Wireless substitution: Early release of estimates from the National Health Interview Survey, July-December 2008. National Center for Health Statistics. May 2009. Available from: http://www.cdc.gov/nchs/nhis.htm.*

***Nielsen Meter sample: 7/6/2009 to 8/2/2009, ***Nielsen Meter sample 12/14/2009 to 1/10/2010*

The Nielsen estimates indicate significantly fewer "No Phone" or "Landline Only" households and considerably more "Cell and Landline" households when compared to the NHIS estimates. The differences in "Landline Only" and "Cell and Landline" may be partially attributed to the (roughly) 10 month difference in measurement period where cellular phone growth may have occurred among previously landline only homes whose inhabitants may be "late adopters" of cell phones. However, recent trends in the NHIS data indicate that "Cell and Landline" has only increased by about 1 percent from year to year during the last few years, while "Landline Only" has been decreasing at a rate much closer to what the Nielsen estimates indicate from mid-2008 to late 2009 (i.e. 2-3 points). Further, by this same logic, we would expect a much higher penetration of "Cell Only" households which in this case varies little between the NHIS and Nielsen estimates. It is possible that the "wireless substitution" phenomenon has begun to reach a saturation point where "substitution" is less about *replacing* landline phones with cellular phones and more about households acquiring cellular telephones *in addition* to existing landlines; though at this stage (and given data, definitional, and period differences between these estimates) this is little more than conjecture. Finally, while "No Phone" is almost half of what is indicated in the NHIS estimates, recent trends have indicated a decline; however, the magnitude of these differences could likely be attributed to sampling error given how few "No Phone" households were in the sample for either Nielsen measurement period[6]. A comparison using NHIS and Nielsen telephone estimates across Census Regions reveals similar trends to those found at the national level.

[6] As an example, no phone households represented only 115 of 20,634 metered households in the NPM panel for the February 2010 measurement period.

Table 2: Comparison of Nielsen October 2009 Universe Estimates to 2008 NHIS PUMS Data by Region

October 2009 Nielsen TV Households Universe Estimate*								
	% of Region				% of Total			
Region	No Phone	LL Only	Cell Only	Cell & LL	No Phone	LL Only	Cell Only	Cell and LL
Northeast	0.6	14.2	12.2	73.0	0.1	2.6	2.2	13.2
Midwest	0.8	12.1	22.6	64.5	0.2	2.8	5.1	14.7
South	1.3	12.3	22.4	63.9	0.5	4.6	8.4	23.8
West	0.7	11.6	19.5	68.3	0.1	2.5	4.3	14.9
NHIS PUMS for Households 2008**								
Northeast	1.4	23.6	12.3	62.8	0.2	4.2	2.2	11.1
Midwest	2.4	19.3	20.9	57.4	0.6	4.6	5.0	13.6
South	2.5	16.8	22.3	58.3	0.9	6.2	8.2	21.4
West	2.1	19.5	17.0	61.4	0.5	4.3	3.7	13.4
Comparison								
Northeast	-0.7	**-9.4**	0.0	**10.2**	-0.1	-1.6	0.0	2.1
Midwest	-1.7	**-7.2**	1.7	**7.1**	-0.4	-1.8	0.2	1.0
South	-1.2	**-4.5**	0.1	**5.6**	-0.4	-1.6	0.2	2.5
West	-1.4	**-7.9**	2.5	**6.9**	-0.3	-1.7	0.5	1.5

**Meter sample: 7/6/2009 to 8/2/2009, **Authors tabulations of the 2008 NHIS PUMs Files*

Table 3: Comparison of Nielsen October 2009 Universe Estimates to 2008 NHIS PUMS Data by Region for Hispanic Households***

October 2009 Nielsen TV Households Universe Estimate*								
	% of Region				% of Hispanic			
Region	No Phone	LL Only	Cell Only	Cell & LL	No Phone	LL Only	Cell Only	Cell & LL
Northeast	1.1	17.6	14.6	66.7	0.2	2.6	2.1	9.7
Midwest	2.7	11.2	36.5	49.6	0.2	1.0	3.1	4.3
South	3.1	7.3	37.6	52.0	1.1	2.7	13.8	19.1
West	1.1	11.7	22.4	64.7	0.5	4.7	9.0	26.0
NHIS PUMS for Households 2008**								
Northeast	4.4	27.0	17.6	51.1	0.6	3.8	2.4	7.1
Midwest	3.8	19.5	27.1	49.6	0.3	1.7	2.3	4.2
South	4.4	15.5	35.0	45.2	1.7	5.8	13.2	17.0
West	3.1	20.9	20.9	55.1	1.2	8.3	8.3	22.0
Comparison								
Northeast	-3.2	**-9.4**	-3.0	**15.6**	-0.4	-1.2	-0.3	2.6
Midwest	-1.1	**-8.3**	**9.4**	0.0	-0.1	-0.7	0.8	0.0
South	-1.3	**-8.2**	2.7	**6.8**	-0.5	-3.2	0.6	2.1
West	-2.0	**-9.1**	1.5	**9.6**	-0.8	-3.6	0.7	4.0

**Meter sample: 7/6/2009 to 8/2/2009, **Authors tabulations of the 2008 NHIS PUMs Files*
****Ethnicity determined by Head of House (or head of primary family if Head of House is not identified in NHIS PUMS)*

Regional estimates for *all* phone statuses are typically not published in the standard "Wireless Substitution" reports produced by Blumberg and Luke, necessitating the usage of the NHIS PUMS data (wherein Census Region is the smallest geographic area available for tabulation). Like the National level comparisons, the Nielsen estimates tend

to be lower for “Landline Only” and higher for “Cell and Landline” households across all regions, though regional trends are comparable between Nielsen and NHIS: “Cell Only” and “No Phone” tends to be highest in the Midwest and South, while landlines (be it alone or in combination with a cell phone) are highest in the Northeast. Results for Hispanic households are comparable, with the exception of large differences in “Cell Only” within the Midwest; whether this difference is meaningful requires further investigation (both in general and for Hispanic households in particular). At a finer resolution, comparisons to modeled state estimates based on the NHIS (Blumberg et. al. 2009) are difficult given the considerable temporal periods of the estimates, though encouragingly most of the highest cell-phone states identified by Blumberg et. al. were also found to have a high prevalence of cell phone households in the Nielsen estimates (Oklahoma, Utah, Nebraska, Idaho, and Iowa).

The smallest geographic area the Nielsen estimates were calculated for was the DMA level. As of the February 2010 estimation period, there are 210 DMAs across the U.S., allowing for more than four times the analytic resolution at the DMA geography level compared to a state level analysis. The relationship of DMAs to states is somewhat sporadic: In some states multiple DMAs are contained in a single state, others cover the entirety of a state, and still others are contained in multiple states. However, their relative correlation to central metropolitan statistical areas allows for analyses of phone statues at the DMA level to be informative even for those not specifically interested in television measurement. Because DMA definitions are fairly esoteric outside of television measurement, the results of the DMA level estimates for February 2010 are presented as choropleth maps in the appendix.

The DMA-level results for each map are compared in terms of their relative magnitude in comparison to the national penetration of the two cell phone status configurations (alone and with landline) as of the February 2010 measurement period. Overall, several broad trends are evident. The heaviest cell phone only areas are predominately in Texas, New Mexico, and Arizona, and up through Kansas and Nebraska. A secondary cluster spreads from the state of Washington up through Idaho, in addition to less dense areas in Central/Southern Illinois and the south east coast running through north-central Florida. Lower penetrations of cell phone only permeate the Northeast U.S. in addition to the majority of California. Cell and landline penetrations tend to be predominately clustered around the largest metropolitan areas in the U.S., including the general New York, Pittsburgh, Boston, Chicago, Los Angeles, San Francisco, Las Vegas, Miami, Minneapolis, Tulsa, Atlanta, Charlotte and Dallas/Austin areas, among others. Large clusters of relatively low landline and cell phone households are found in the Central and Northwestern portions of the U.S., in addition to the majority of the state of Maine.

Of particular interest for RDD or other telephone frame based survey efforts, even attributing a high degree of possible error to these estimates, the spatial density of several of these areas by phone status indicate not only that cell phone only household prevalence does not fall nicely within regional or even state boundaries, but also that some degree of regional differentiation or clustering can be expected. In other words, particular areas of United States might be more or less prevalent for cell phone only households. Meanwhile, other areas may exclude less of the possible sampling universe by relying upon telephone frame surveys due to the comparatively low concentration of cell phone only households (though demographic differentiations among cell phone only households compared to others households almost certainly remain). Ultimately, any new insights which can be extracted from these results is heavily contingent upon how well they

measure the actual status of cellular adaptation in the U.S. The results from the aforementioned variance tests suggest that reliably estimating phone statues at a sub-national level may continue to be a challenging prospect for interested parties.

Table 4: Reporting Test Results by Telephone Status: September-December 2009, December 2009 - March 2010

Technology by Period	1-Tail Positive ("Growth")		1-Tail Negative ("Decline")		2-Tail ("Difference")	
	% p-values <.10	*% Rel Diff >5% & p-values<.10*	*% p-values <.10*	*% Rel Diff >5% & p-values<.10*	*% p-values <.10*	*% Rel Diff >5% & p-values<.10*
Cell Only						
Sep '09-Dec '09	56.4/44.4	56.4/44.4	1.8/2.8	**1.8/2.8**	43.6/30.6	43.6/30.6
Dec '09-Mar '10	60.0/47.2	60.0/47.2	0/0	**0/0**	45.5/38.9	45.5/38.9
Non-Landline						
Sep '09-Dec '09	56.4/38.9	56.4/38.9	1.8/2.8	**1.8/2.8**	41.8/25.0	41.8/25.0
Dec '09-Mar '10	61.8/52.8	61.8/52.8	0/0	**0/0**	43.6/36.1	43.6/36.1
Cell & Landline						
Sep '09-Dec '09	7.3/8.3	**0/0**	30.9/27.8	**5.5/5.6**	23.6/19.4	**5.5/5.6**
Dec '09-Mar '10	5.5/5.6	**0/0**	25.5/16.7	**5.5/8.3**	18.2/13.9	**5.5/8.3**
Landline Only						
Sep '09-Dec '09	1.8/2.8	**1.8/2.8**	40.0/30.6	40.0/36.6	27.3/25.0	27.3/25.0
Dec '09-Mar '10	1.8/2.8	**1.8/2.8**	40.0/38.9	40.0/38.9	30.9/30.6	30.9/30.6
No Phone						
Sep '09-Dec '09	3.6/2.8	**3.6/2.8**	7.3/8.3	**7.3/8.3**	3.6/5.6	**3.6/5.6**
Dec '09-Mar '10	16.4/19.4	16.4/19.4	10.9/13.9	10.9/13.9	5.5/8.3	**5.5/8.3**

Percentage of markets meeting criteria: All Metered Markets (55) / Eligible Metered Markets (36)
Passing results are in bold (5 Rel Diff>5% and p-values <.10 only

Expectedly, period to period variance for markets eligible to be tested is considerable. Because meter markets represent the largest and most diverse areas in the U.S. both demographically and socioeconomically (i.e. the largest metro areas in the U.S.), and data may be obtained from the metered sample much more frequently than diary-measured markets which adhere to specific "sweep" measurement periods, the tests to determine whether the calculated UEs may be considered "official" is conducted only on markets with metered television measurement (55 of the 210 television markets). Of the metered markets, only a sub-set of 36 markets are eligible to determine whether a particular estimate passes for a given period. Eligible markets are those which transitioned to area probability and/or ABS sampling at a time sufficiently distant from the test period to insure that no previous telephone frame selected households are included in the respective market's samples.

These test results indicate not only a large degree of variance from period to period, but also that the standard "growth" test usually implemented for media characteristics would not be a sufficient measure of the bipolar directionality of telephone statuses. One-tailed tests for either positive or negative only values indicate that the predominate direction of change for the phone status UEs differs depending on which household phone configuration is analyzed. Of which, almost half of the tested markets with positive change in cell phone only households exhibited significant period to period differences and relative differences in excess of 5%, while virtually no markets demonstrated significant differences for negative period to period changes. These findings seem to

dismiss the possibility of "wireless substitution" transfiguring into "wireless supplementation" as previously postulated given the preponderance of markets with strong positive growth between both measured periods. Non-landline households (i.e. both no phone and cell only households) produced analogous results, though the number of markets with high amounts of variance is somewhat dampened in this case given the inclusion of the more stable no phone estimates. Intuitively, the inverse is true for landline only households: Almost no markets produced significant positive growth while over a third produced negative growth. Landline only households exhibit both negative one-sided p-value and two-sided test reveal period to period differences well in excess of acceptable levels. Comparatively, while exhibiting unacceptable variance in the one-tailed tests, two-tailed differences are within the acceptable bandwidth of variability. Of all the phone configurations, only cell & landline households meet criteria for all possible tests and testing periods. The relative stability of these estimates across both periods for the vast majority of metered markets provides support for the reliability of the estimates despite the large disparities between these UEs and the NHIS results.

In summary, of the four possible phone statuses, only cell & landline is stable enough for semi-reliable estimation. These results provide empirical data of both the direction and magnitude of telephone adaptation in the U.S. in principally metropolitan areas. Between the tested periods, cell only and non-landline households both demonstrated strong, statistically significant, positive growth for almost half of the measured markets. Landline only households demonstrated statistically significant and negative changes for over a third of the measured markets. No phone households were much more stable, though the direction of the change is considerably more mixed, indicating that the prevalence or decline of no phone households may be strongly dependant upon the particular geographic region or area which is measured. However, given the very small number of no phone households, it is likely that sundry sampling variance is at play.

4. Discussion and Implications

Dimensioning the effect of cell phone adoption on telephone frame coverage and/or bias has been made all the more difficult given that the prevalence of this phenomenon has largely been an unknown. While sources of information and relevant analyses still lag considerably behind the growing prevalence of this phenomenon, measuring phone statuses in the U.S. is now less of an unknown and more of a "moving target" for interested parties. This paper adds to this growing collection of knowledge about the prevalence of particular household phone configurations in the U.S. However, like many analyses and sources of information before it, many results are problematic and perhaps just as many questions have been posed as answers furnished.

Where comparable, estimates resulting from the Nielsen media-related UE system demonstrate distinct differences from the now standard NHIS estimates. Specifically, Nielsen estimates at a national and regional level indicated significantly more cell & landline households and considerably less landline only households. Meanwhile, cell only households were largely consistent between the two sets of estimates even with the considerable duration of time separating the estimate dates. This would seem to indicate that cell only households have reached a critical penetration point at around 20%, and wireless "substitution" is being transfigured into wireless "supplementation" where most landline households are adopting cell phones in addition to their landlines as opposed to replacing their landlines with a cell phone. Such a thesis seems to be partially dissuaded by period to period variance tests for phone statuses which indicate that cell only

households (at a market level) still exhibit considerable growth while cell & landline households were comparatively stable. However, given the stability of cell & landline households and the overall stability of cell phone only penetrations at the national and regional level over a large and differential period of time, it may be premature to dismiss the plausibility of such a shift in cell phone adoption at this point in time.

When the analytic resolution is increased to the 210 Nielsen television markets, several broad trends for the different phone statuses become apparent. These findings indicate that phone status estimates do not follow state and regional lines, and particular geographic areas may be more or less prone to problems associated with telephone sampling. However, results from the growth tests imply considerable change in period to period estimates of phone statuses. While the direction of these differences is mostly uniform and intuitive, it further reinforces the point that estimates of households by telephone status may largely be outdated almost as quickly as they can be produced.

This last finding in particular does not bode well for the prospect of phone status becoming a reliable weighting control for Nielsen's samples until the growth of these characteristics stabilize. While small-area estimates of cell phone households have been a long needed and seldom fulfilled need for the survey research community, these results indicate that even with a large, nationally representative, and high quality sample, the resulting estimates could only be used with caution. The implication on this point seems to be a need for sophisticated statistical modeling and projections of cell phone estimates based upon a rich data source beyond what is afforded (at this time) in the media-related estimate creation system. Relying only upon collected disposition data, be it from the NHIS or Nielsen panels, will almost certainly be insufficient until the rate of change in household telephone configuration begins to level off; a prospect which seems largely unlikely based upon the magnitude of period to period differences found here. Advanced modeling and projection methodologies are thus a fruitful direction for further work on cell phone adaptation given the relative inability of standard population projection methods to dimension this phenomenon at this time.

This is not to say, however, that all sub-national estimates are without merit or usefulness. The tests above indicate it is reasonable to assume that some configurations of cell phone adoption in the U.S. can be measured with a degree of reliability. Even with the considerable change from period to period, the market level estimates seem to indicate concentrated "pockets" of household phone statuses across the U.S. These results may allow for some degree of rudimentary sub-national weighting given an assumption of differential phone statuses in particular areas of the U.S.

Ultimately, results here imply that reliable sub-national estimates for phone statuses (and thus the affiliated weights) may be a long time off, though perhaps not an impossibility. In the interim, statistical projections and models coupled with "preliminary/working" estimates such as these may partially compensate for this information void until fully reliable estimates can be produced for sub-national geographies on a regular basis. Such "methodological combinations" may be necessary going forward as the diversity of home communication technology will only continue to change. If the prevalence of cell phones in the U.S. is any indicator, at this time survey research methods will continue to have a difficult time catching up. Thus, processes and systems for creating weights and population methods must strive to be adaptive and contemporary. Such a paradigm shift will likely introduce additional computational error in the results of the affected surveys. However, like all matters in survey research, trade offs are both a reality and a necessity.

While typically trades offs are between cost and error minimization, adding a balance of computational error for increased representativeness of the results may soon be a salient and pressing issue.

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Appendix: Supplementary Figures