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RESEARCH SYNTHESIS
THE CHANGING ROLE OF ADDRESS-BASED SAMPLING IN SURVEY RESEARCH

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Abstract Address-Based Sampling (ABS) is increasingly viewed as a potential remedy for the rising costs associated with in-person surveys of the U.S. general population, and for the dwindling coverage associated with telephone surveys. For small and moderate-sized surveys, ABS can help make in-person interviewing a viable mode of data collection. For large-scale studies, ABS can enable the transfer of resources from frame development to activities like training for refusal conversion, an examination of total survey error, or a nonresponse follow-up study. A synthesis of research studies estimating ABS coverage for in-person surveys shows nearly complete coverage of the household population in urban areas and varying degrees of undercoverage in rural areas. Less is known about ABS coverage of non-household populations, such as college students living in dormitories or persons residing in other group quarters. This research suggests the holistic question: Does the expediency of ABS outweigh the undercoverage that may accompany its use? The answer depends on the population being studied, the mode of data collection, and the effectiveness of frame supplementation methods. This article summarizes the current literature on the advantages and challenges of using ABS for in-person surveys as well as for mail and mixed-mode surveys.

Read this article quickly. By the time you're finished, parts of it will likely be out of date. The use of residential address lists as a sampling frame for surveys has increased dramatically in a short period of time. Before the U.S. Postal Service (USPS) began making electronic files of mailing addresses available to the public through qualified companies in the early 1990s, the only commercially

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available address lists were those generated by vendors for direct-mail marketing purposes. As a result, the coverage of households in low-income areas often was incomplete. In fact, the use of such lists contributed to the undercount for the 1990 Census (U.S. Census Bureau 2001). In reaction to the undercount, the Census Bureau began construction of their Master Address File for the 2000 Census using a list of mailing addresses provided by the USPS.

Around the same time, commercially available mailing addresses began to be considered as an alternative to the costly and time-consuming process of area sampling for in-person household surveys. The first published evaluation of the use of mailing addresses for an in-person household survey in the United States was a probability-based survey of 15,000 households in Dallas County, Texas, conducted in 2000 (Iannacchione, Staab, and Redden 2003). The evaluation found that a sampling frame of mailing addresses provided nearly complete coverage of the metropolitan area at a cost that was about a tenth of area sampling. A more widespread evaluation of coverage for a subset of the General Social Survey followed in 2001 and 2002 (O'Muircheartaigh, Eckman, and Weiss 2003). This study found that the coverage of mailing addresses for in-person surveys was problematic in rural areas because of a disproportionate number of households with P.O. boxes or rural route boxes.

In the decade since these early studies, the use of mailing address lists for surveys—now known by the moniker of *address-based sampling* (ABS)[1]—has become an integral component of the sampling frames of such well-established in-person household surveys as the National Survey of Family Growth (Lepkowski et al. 2010), the American National Election Study (Lupia et al. 2009), and the General Social Survey (O'Muircheartaigh et al. 2009). In addition, ABS has replaced random digit dialing (RDD) as the sampling methodology for the Nielsen TV Diary service (Bailey, Grabowski, and Link 2010), and Knowledge Networks now recruits households for its KnowledgePanel® using an ABS frame instead of RDD (DiSogra, Dennis, and Fahimi 2010).

The ubiquity of ABS is now beyond question: A keyword search of "ABS" produced 19 articles in the 2010 *Proceedings of the American Statistical Association*; a recent Google search of "address-based sampling" produced 7,360,000 hits. The prolific use of ABS for surveys has produced a wide variety of claims about its usefulness with respect to coverage, cost savings, and its effect on response rates. Further, the ongoing changes in the frequency of some types of mailing addresses (e.g., simplified addresses)[2] make some research findings obsolete soon after publication. Even understanding the basic terminology associated with the use of mailing addresses (e.g., a city-style address) can be problematic. Faced with such a diversity of results, it may be difficult for

1. The term "Address-Based Sampling" as it applies to the use of mailing addresses as a sampling frame for the U.S. general population was first cited in Link et al. (2008).

2. Simplified addresses do not include a street name and number. Instead, the address label displays "Occupant," city, state, and ZIP Code.

survey researchers to evaluate the validity of ABS when applied to their particular application.

The goal of this research synthesis is to advance the use of ABS for surveys by answering three questions. First, what are the sources and types of mailing addresses that are available to survey researchers? Second, what are the dominant paradigms of ABS for in-person, mail, and mixed-mode surveys? Finally, what are the challenges facing the use of ABS for survey research?

Residential Mailing Addresses

DATA SOURCES

In this article, the term *ABS* refers to the use of residential mailing addresses as a sampling frame for surveys of the U.S. civilian non-institutionalized population. Residential mailing addresses are made available to the public by qualified private companies that have a nonexclusive relationship with the U.S. Postal Service (USPS) to update their data. All postal products are derived from the USPS Address Management System.[3] The USPS offers the mailing industry different types of data products for a variety of purposes. Among those of particular interest to survey researchers are the Delivery Sequence File Second Generation (DSF$^{2®}$; USPS 2009a) and the Computerized Delivery Sequence File (CDS; USPS 2009b).

These and all data products offered by the USPS are governed by U.S. Code Title 39, Section 412, which prohibits a mailer or research company from receiving postal mailing addresses directly from the USPS. For example, access to the DSF$^{2®}$ will help a mailer obtain accurate delivery address information and facilitate the identification of erroneous addresses, but it can be applied only to a mailer's existing address files. Further, the USPS licenses the DSF$^{2®}$ only to companies that pass stringent testing and pay a licensing fee to the USPS for access to these data.

The CDS product contains the same delivery information as the DSF$^{2®}$. To qualify for the CDS, a company must demonstrate that it possesses at least 90% (but not more than 110%) of the current mailing addresses in a ZIP Code for which it wishes to receive CDS updates. Once demonstrated, the USPS will, on either a weekly or bi-monthly basis, update the company's list (i.e., remove erroneous addresses and add missing addresses) for an annual subscription fee. This updating process distinguishes the CDS from the DSF$^{2®}$.

Studies by Dohrmann, Han, and Mohadjer (2006) and Kennel and Li (2009) found that companies holding a CDS license were able to offer a more complete address list than those that merely cleaned their own list using DSF$^{2®}$. As of this writing, Valassis (2011) and Compact Information Systems (CIS, 2011) are the only two companies holding a nearly complete national CDS license. Both

3. A list of Address Management System data products is available at http://www.usps.com/ncsc/addressmgmt/addressmgmtmenu.htm.

companies receive weekly updates of the CDS, and both provide mailing addresses to end users and list resellers.

Although all addresses on commercially available mailing lists are available for survey research purposes, vendors routinely delete the addresses of persons who indicate that they do not wish to receive direct mail.[4] The non-profit Direct Marketing Association (DMA) maintains a national do-not-mail list (www.DMAchoice.org) that enables organizations that conduct mailings to exclude addresses of consumers who indicate they do not want to receive direct mail. In December 2010, the DMA do-not-mail list contained over 4.1 million addresses nationwide. To avoid undercoverage, survey researchers should specifically request that addresses on the do-not-mail list be included in their purchase.

BASIC ELEMENTS OF A MAILING ADDRESS

The basic data elements of a mailing address include street/box number, city, state, nine-digit ZIP Code, carrier route number,[5] and the delivery-sequence number that corresponds to the order in which a letter carrier delivers mail. In addition, the mailing record includes a USPS vacant address indicator flag for city-style addresses, and a seasonal flag for seasonal delivery. Seasonal and vacant flags are assigned at the discretion of the local post office using internal postal guidelines.[6]

The types of mailing addresses that are most relevant to surveys can be categorized into the following six categories:

(1) *Locatable city-style addresses*. These addresses contain a street name and number, city, state, and ZIP Code. If applicable, the unit type and number of the address (e.g., APT 14) also is included.
(2) *Drop points*. These are locatable city-style addresses, but they do not contain the unit type and number. Mail is delivered for distribution to multiple internal drop units within a drop point (e.g., a gated community). The number of internal drop units associated with a drop point is included in the record.
(3) *Residential post office (P.O.) boxes*. Residents who live in areas with home mail delivery may also receive mail at a rented residential P.O. box. In areas where home delivery is not provided, the USPS provides free (*aka* Group E) P.O. box service to household residents (USPS 2010a). Because the "Group E" P.O. box designation is not passed along as a field in the record, vendors have developed their own proprietary

4. Direct mail is printed matter prepared for soliciting business or contributions and mailed directly to individuals.
5. The five carrier route designations are city (C), rural (R), highway contract (H), general delivery (G), and P.O. box (B).
6. USPS guidelines specify that a vacant address is an address that has been unoccupied for 90 days or more.

methodology for identifying households whose "only way to get mail" (OWGM) is through a P.O. box.

(4) *P.O. box throwbacks*. This type identifies a locatable city-style address on a city carrier route that receives mail at a P.O. box rather than the residential address, per the customer's request. Only first-class mail will be forwarded to the P.O. box for a throwback. The connection between a P.O. box throwback and its locatable address cannot be disclosed due to USPS privacy restrictions.

(5) *Rural route (RR) and highway contract (HC) boxes*. These addresses have not gone through the USPS Locatable Address Conversion System, which provides mailers with an automated method to convert RR and HC boxes to locatable city-style addresses (e.g., RR 1 BOX 32 converted to 141 MORRISON AVE).

(6) *Simplified addresses.* These addresses do not include a street name and number. Instead, the address label displays "Occupant," city, state, and ZIP Code. Typically, an entire carrier route will contain simplified addresses, making them impractical for most survey applications.

A total of 137,516,347 residential delivery points are shown in the USPS 2010 Annual Report (USPS 2010b). In July 2010, Valassis was licensed to receive all but 35,000 delivery points on the CDS, while CIS was licensed to receive all but 80,000 delivery points.[7] The distribution of residential mailing addresses on the Valassis saturation list for July 2010 is shown by type of address in table 1. Because the Valassis and CIS lists were nearly the same size in July 2010, the distribution of the CIS residential list was very similar to that of Valassis.

A wide range of additional data may be appended to the basic mailing address by commercial vendors with varying levels of accuracy and completeness. These include but are not limited to telephone number, resident name(s), geographic coordinates, number of adults, age and race/ethnicity of householder, homeownership (rent/own), and household income. DiSogra, Dennis, and Fahimi (2010) compared a number of household demographic variables purchased from Marketing Systems Group (MSG) to interview responses from the KnowledgePanel®, which is based on an ABS sample. The highest correlations (Pearson-R between 0.608 and 0.675) were for homeownership, age of householder, and race/ethnicity of householder. The missing data rate for the variables in the MSG file ranged from 5% to 27%.

Since 2009, companies holding a CDS license also have access to the USPS CDS No-Stat file (USPS 2009b), which supplements the CDS file with the following information:

7. E-mail communications with Pat Wiley of CIS and Anne Connelly of Valassis.

Table 1. Distribution of Residential Mailing Addresses on the Computerized Delivery Sequence (CDS) File by Type of Address

Type of Address	Number of Addresses	Percent (%)
Locatable City-Style[1]	118,988,021	86.5
Drop Point[2]	2,339,440	1.7
PO Box Throwback[3]	295,447	0.2
RR Box or HC Box[4]	380,206	0.3
OWGM PO Box[5]	1,684,196	1.2
Not OWGM PO Box[6]	13,804,535	10.0
Simplified[7]	22,000	0.0
Total	137,513,845	100.0

SOURCE.— Valassis Saturation File as of July 2010. Includes all but 35,000 addresses in the residential portion of the CDS file.

[1] A locatable city-style address contains a street name and number, and if applicable, a unit type and number (e.g., APT 3).

[2] A drop point contains a street name and number but not a unit type and unit number. The 2,339,440 drop units are associated with 786,419 drop points.

[3] A residence on a city carrier route that has mail delivered to a P.O. box instead of the residence. The street address of the residence is in the CDS file.

[4] Rural route box or Highway contract box.

[5] Proprietary indicator developed by Valassis to identify households whose ''only way to get mail'' (OWGM) is through a P.O. box.

[6] P.O. boxes assigned to residences that also receive home mail delivery.

[7] Simplified addresses do not contain a street name and number. Instead, the address label typically displays ''Occupant,'' city, state, and ZIP Code.

- Addresses on rural and highway contract carrier routes that have been vacant for 90 days or longer. These complement the vacant addresses for city routes that are in the CDS file.
- Locatable city-style addresses for P.O. box throwbacks on rural and highway contract carrier routes. These complement the P.O. box throwbacks for city routes that are in the CDS file.
- Locatable city-style addresses including unit type and number, e.g., APT 14. In November 2010, unit type and number were available for approximately 6% of the units within drop points.
- Addresses of residences under construction. These can range from ground not even broken to nearly completed construction.

The distribution of residential mailing addresses on the CDS No-Stat file by type of address is shown in table 2.

Table 2. Distribution of Residential Mailing Addresses on the USPS CDS No-Stat File by Type of Address

Type of Address	New Growth[1]	Not New Growth	Total	Percent (%)
Internal Drop Address[2]	1,344	145,991	147,335	1.8
Rural PO Box Throwback[3]	2,071	685,907	687,978	8.4
Rural Vacant Address[4]	25,842	6,468,581	6,494,423	79.5
City Vacant Address[5]	9,696	830,027	839,723	10.3
Total	38,953	8,130,506	8,169,459	100.0

SOURCE.— Valassis download of the residential portion of the USPS CDS No-Stat file, November 2010. Counts verified by the USPS.

[1] An address for a residence under construction, which can range from unbroken ground to nearly completed. Note that throwbacks are not categorized as new growth in the CDS User's Guide.

[2] The complete address including unit type and number (e.g., APT 29) for a drop point such as a gated community.

[3] A residence on a rural or highway contract carrier route that has mail delivered to a P.O. box instead of the residence. The address of the residence is in the No-Stat file.

[4] An address on a rural or highway contract carrier route that has been vacant for 90 days or longer.

[5] An address on a city carrier route that has been vacant for 90 days or longer.

The union of the CDS and CDS No-Stat files provides an estimate of the total number of occupied, vacant, and seasonal housing units (HUs)[8] in the United States. The estimate can be obtained by adding the number of residential mailing addresses in the CDS file (less P.O. boxes assigned to residences that also receive home mail delivery) with the number of residential mailing addresses in the CDS No-Stat file (less new growth and internal drop addresses). The corresponding entries in tables 1 and 2 yield an estimated 131,693,000 active and vacant residential mailing addresses. By comparison, there were an estimated 131,158,000 occupied, vacant, and seasonal HUs in the United States during the second quarter of 2010 (U.S. Census Bureau 2010). Although there is not a strict one-to-one relationship between mailing addresses and HUs, the similarity of the estimates provides some evidence that the mailing address of nearly every HU in the United States can be found in either the CDS file or the CDS No-Stat file.

8. A housing unit is a house, apartment, or other group of rooms, or a single room that is occupied or intended for occupancy as separate living quarters; that is, when the occupants do not live and eat with any other persons in the structure and there is direct access from the outside or through a common hall. A household consists of all the people who occupy a housing unit (U.S. Census Bureau 2008).

Using ABS for In-Person Surveys

The ubiquity of mailing addresses facilitates the use of ABS for in-person, mail, and mixed-mode surveys. However, in-person interviewing offers several distinct advantages over other modes of data collection. These include:

- The presence of a trained interviewer who can answer questions about the questionnaire and about the survey itself;
- The use of audio-computer-assisted self-interviewing for sensitive questions such as sexual and drug-use behaviors (Harmon et al. 2009); and
- The collection of biospecimens and paradata (Kreuter et al. 2010).

Unfortunately, the expense of in-person interviewing often restricts its use to large-scale, federally funded surveys that place a premium on high coverage rates, high response rates, and high data quality (Groves et al. 2004).

ABS is increasingly viewed as an alternative to the high cost associated with *area sampling* (Kish 1965, pp. 301–58), which often is assumed to be the "gold standard" for frame construction for in-person surveys of the civilian, non-institutionalized U.S. population. Area sampling begins by partitioning the geographical area associated with the survey population into small areas known as *segments*. Typically, a segment is defined as one or more contiguous U.S. Census blocks with an approximate measure of size, e.g., number of HUs. The use of Census geography provides complete geographic coverage and facilitates area sampling because the boundaries are based on known landmarks whenever possible.

Conceptually, area sampling includes all HUs in a selected segment. In practice, however, enumerators may miss potential HUs because of carelessness or insufficient training, or they may make errors such as listing a unit that appears to be a single-family home but actually contains multiple HUs. In other situations, HUs may be missed because they are difficult to view from roads, or may be contained within locked buildings or gated communities that cannot be easily accessed. O'Muircheartaigh, English, and Eckman (2007) report that areas undergoing redevelopment or change can be difficult to enumerate. A national validity study of area sampling (Cunningham et al. 2006) estimated a net undercoverage rate of 4.9% of the civilian, non-institutionalized U.S. population, with a greater percentage of enumeration errors occurring in rural areas than in urban areas.

Frame-linking procedures are used to reduce undercoverage and typically are administered during the data-collection phase of a survey. The Half-Open Interval (HOI) frame-linking procedure (Kish 1965, p. 56) theoretically adds HUs to an existing area sampling frame by searching for new or missed units in the interval between the sampled HU and the next HU in the frame. To be effective, the HOI procedure requires that the HUs in the frame be sorted in geographically proximal order. Enumerators achieve this ordering by following a "path of travel" that places adjacent HUs in consecutive order whenever possible.

During field interviewing, missed HUs discovered in the HOIs are assigned a positive probability of being included in the sample.

SOURCES OF ABS UNDERCOVERAGE FOR IN-PERSON SURVEYS

The undercoverage associated with area sampling is primarily the result of currency and human error. In contrast, the primary sources of ABS undercoverage for in-person surveys are households with unlocatable mailing addresses and geocoding error.

Unlocatable Mailing Addresses: Although it is not unreasonable to assume that virtually every household in the United States has a mailing address, not all mailing addresses are suitable for in-person surveys because interviewers must be able to locate a mailing address "on the ground." Mailing addresses that do not provide a direct link with the physical location of households include P.O. box numbers, RR and HC box numbers, and simplified mailing addresses.

Although P.O. boxes account for more than 11% of the residential addresses in the CDS file, most can be excluded from an ABS frame without loss of coverage because most renters of P.O. boxes also have mail delivered to their street address. P.O. boxes are a source of undercoverage for in-person surveys for households that are located in areas where home delivery of mail is not provided. The "only way to get mail" (OWGM) for these households is through a P.O. box. Staab and Iannacchione (2003) estimated that in 2002 approximately 1.42 million households nationwide were located in areas with no home mail delivery. This is similar to the 1.68 million OWGM addresses offered by Valassis in July 2010, and the 1.70 million OWGM addresses offered by CIS during the same time period.

Several studies have found that ABS coverage for in-person household surveys is problematic for rural areas (Dohrmann, Han, and Mohadjer 2007; O'Muircheartaigh, English, and Eckman 2007; Iannacchione et al. 2007) because households in rural areas contain a disproportionate share of unlocatable mailing addresses. However, the prevalence of RR and HC boxes is diminishing because E-911 programs are encouraging local governments to use locatable city-style addresses to facilitate location by emergency service vehicles. For example, there were 4.2 million RR and HC boxes in 2002 (Staab and Iannacchione 2003), compared to only 380,000 in 2010 (table 1). In addition, the number of simplified addresses has been drastically reduced from approximately 2.4 million in 2006 (Iannacchione et al. 2007) to only 22,000 in 2010 (table 1).

Geocoding Error: Geocoding is the process of converting locatable city-style mailing addresses into geographic coordinates (latitude and longitude). The use of Census geography for an ABS frame requires geocoding to capture the physical location of a city-style address because Census information (e.g., the Census block) is not part of the standard mailing address. Geocoding errors occur

when the geocoded approximation of the location of an HU is not the same as the actual physical location of the HU.

Vendors use geocoding to *approximate* the Census geography (e.g., Block, Block Group, and Tract) associated with a mailing address. However, the positional inaccuracies inherent in the geocoding process (e.g., Bichler and Balchak 2007) can result in undercoverage (i.e., the exclusion of addresses that are physically located inside a sampled segment) and overcoverage (i.e., the inclusion of addresses that are located outside a sampled segment). O'Muircheartaigh et al. (2009) and Shook-Sa et al. (2010) report that geocoding errors are more prevalent in rural segments than in urban segments. Montaquila, Brick, and Curtin (2010) cite concerns about undercoverage and geocoding error associated with the use of ABS for the National Children's Study.

In practice, the geocoding errors associated with an ABS frame can be avoided by defining segments based on "postal geography" and then having a vendor query the database for all mailing addresses with a sampled ZIP Code and/or postal carrier route. However, the use of postal geography for sampling purposes has three distinct disadvantages compared to Census geography:

(1) Carrier routes do not completely cover geographic areas. The lack of geographic coverage is pronounced in some rural areas and is nonexistent in areas that do not have home delivery of mail.
(2) Carrier routes are dynamic and may be expanded or combined with other routes. These changes complicate the matching of external demographic data that often are used to inform an in-person sampling design.
(3) Postal geography cannot be associated with demographic data available from the American Community Survey and other products provided by the Census Bureau.

A useful product for cross-walking mailing addresses from postal geography to Census geography is the Topological Integrated Geographic Encoding and Referencing (TIGER)/ZIP+4® File (USPS 2007), which relates ZIP+4 coded address lists to Census Bureau demographic data. Note that the coverage of the file is limited to the address ranges in the ZIP+4 product that can be successfully matched to the address ranges in the Census Bureau's TIGER file.

SUPPLEMENTING ABS COVERAGE FOR IN-PERSON SURVEYS

Several frame-linking procedures have been developed to supplement the coverage associated with an ABS frame. For example, Iannacchione, Staab, and Redden (2003) describe a modification of the HOI procedure that uses the route a letter carrier follows to deliver the mail as a measure of geographical proximity. The typical delivery route proceeds up one side of the street and then down the other, making it suitable for the HOI procedure. However, determining an HOI based on a postal delivery route is problematic for clusters of mailboxes,

apartments, and some street intersections. In addition, delivery routes may be disjoint and are nonexistent for HUs located in areas without home delivery of mail.

With *dependent listing* (*aka* update or enhanced listing), enumerators canvass a segment prior to data collection to add addresses of HUs not in the ABS frame and delete those of vacant and demolished HUs (Harter et al. 2010; Groves et al. 2009). However, Eckman and Kreuter (2011) caution that when enumerators are presented with a listing to update in the field, they tend not to add missed units or delete inappropriate units. These failure-to-add and failure-to-delete errors could lead to an overestimate of the coverage of an ABS frame.

Dohrmann, Han, and Mohadjer (2006) describe an enhancement to the "Waksberg Approach," which is a frame-linking procedure that can be applied to either area sampling or ABS. The enhancement attempts to avoid the problem of encountering large numbers of missed HUs by using Census data to oversample segments with high growth. Within a segment, a subsample of HUs not in the ABS frame is selected with probabilities that result in an *epsem* (equal probability of selection method) sample of missed HUs.

The Check for Housing Units Missed (CHUM) frame-linking procedure (McMichael, Ridenhour, and Shook-Sa 2008) is another procedure designed to supplement ABS coverage. The CHUM procedure is similar to the HOI in that the field interviewer locates the sample address and then identifies a "next HU" based on a pre-specified path of travel. If the next HU is on the ABS list, then the CHUM is complete. Otherwise, the missed HU is included in the sample and the protocol is repeated until the field interviewer either encounters an HU with an address on the ABS list or comes to the boundary of the segment.

The CHUM methodology was used for the 2008 American National Election Survey and increased the coverage of the target population by approximately 5.1 percentage points (Lupia et al. 2009). Although the CHUM can be implemented in segments with low ABS coverage, the level of effort needed to enumerate the segment may exceed that of area sampling. Instead, a hybrid frame based on ABS and either area sampling (Iannacchione et al. 2010), GeoFrame™ (Albright et al. 2008), or property tax records (Kalsbeek, Kavanaugh, and Wu 2004) should be considered.

ADVANTAGES OF USING ABS FOR IN-PERSON SURVEYS

The primary advantages of using ABS instead of area sampling as a sampling frame for in-person surveys are timeliness, geographic diversity, and cost savings.

Timeliness: A sampling frame based on ABS can be developed in a matter of weeks instead of the months usually required for area sampling. This time savings enables improved coverage in areas of high growth. Such time savings also gives survey planners time to retarget the sample in reaction to findings obtained from a pilot survey.

Geographic Diversity: Area sampling often requires relatively small segments to enable field staff to completely enumerate a segment. Because ABS does not

require fieldwork prior to sample selection, ABS segments can produce a geographically diverse sample of households with lower intracluster correlations for many estimates as a consequence of more flexibility with respect to size.

Cost Savings: Just as direct mailers use address lists as a cost-effective way of saturating their client base, ABS can be used to develop a sampling frame that costs a fraction of area sampling. For example, ABS was used instead of area sampling to develop a sampling frame for a probability-based in-person survey of 15,000 households in Dallas County, Texas (Iannacchione, Staab, and Redden 2003). The expense of purchasing and processing the entire list of more than 800,000 locatable city-style mailing addresses for Dallas County was estimated to be less than one tenth the cost of area sampling. The cost comparison included the implementation of the modified HOI procedure designed to increase the coverage of the household population.

Unlike the Dallas study, the target population for the 2008 NSDUH included non-institutionalized civilians, some of whom lived in group quarters (GQs) or in households with unlocatable mailing addresses. As a result, a sampling frame based solely on ABS would not yield the same coverage of the target population as the NSDUH frame, which was based exclusively on area sampling.

To achieve the same coverage of the NSDUH population afforded by area sampling, the cost comparison assumed that an ABS frame would be supplemented with the CHUM frame-linking procedure in segments with locatable city-style addresses and replaced with area sampling in segments with concentrations of GQs or unlocatable addresses (Iannacchione et al. 2010). Under these circumstances, a sampling frame for the NSDUH based on ABS with area sampling used in approximately 15% of the 7,200 sample segments would cost about 45% of the cost of a frame based exclusively on area sampling.[9]

Using ABS for Mail Surveys

The mail mode of survey administration offers distinct advantages and disadvantages. On the one hand, the survey topic may be made more salient than, say, a telephone survey because the cover letter, the envelope, and the questionnaire itself all convey information about the study (Groves et al. 2006). On the other hand, the self-administration associated with mail surveys complicates the random selection of one or more persons within a sampled household (Battaglia et al. 2008).

For most mail surveys based on ABS, overcoverage in the form of persons who receive mail from a residential P.O. box in addition to their home address is

9. These cost estimates reflect all statistical, GIS, survey methodologist, field staff labor and expenses, shipping materials, and other direct costs.

more of a problem than undercoverage. For example, the 2007 Health Information National Trends Survey asked households the number of ways they receive mail (including commercial mailboxes) and found that households with P.O. boxes had a mean of 1.24 ways, which was significantly higher than households without P.O. boxes (Norman and Sigman 2009). The selection multiplicity associated with P.O. boxes can be pronounced for mail surveys conducted in urban areas (Iannacchione, Staab, and Redden 2003).

Although there is some evidence that the majority of persons with residential P.O. boxes also have mail delivered to their street address, excluding all P.O. boxes from an ABS frame for a mail survey will undercover households located in areas without home mail delivery. As described in the previous section, many households that receive mail exclusively through P.O. boxes can be identified with a proprietary OWGM indicator offered by some vendors. Although the inclusion of addresses with an OWGM indicator can potentially reduce the undercoverage of this segment of the household population, more research is needed to validate the accuracy of the indicators.

Link et al. (2008) used an ABS frame for a mail survey of adults aged 18 years and older for a pilot study that was conducted in six states as part of the 2005 Behavioral Risk Factor Surveillance System. The pilot compared the use of landline random digit dialing (RDD) telephone survey methodology to an approach using a mail version of the questionnaire completed by a random sample of households drawn from an ABS frame. Response rates for the mail survey approach were at least 4 percentage points higher than those obtained in the RDD surveys in five of the six states studied when two questionnaire mailings were sent. To obtain the same number of interviews, the telephone survey cost would be 12% higher than the mail survey cost.

Using ABS for Mixed-Mode Surveys

In addition to facilitating in-person and mail surveys, ABS can be used for mixed-mode surveys, especially when other forms of contact information such as telephone numbers or e-mail addresses are appended to mailing addresses. The use of multiple modes can improve response rates as well as coverage when compared to many unimodal designs (de Leeuw 2005). However, these advantages must be tempered with research that indicates that different survey modes may result in different answers to the same questions. For example, Dillman and Christian (2005) reported more positive responses to scale questions over the telephone compared with those obtained from the Web.

ABS has been evaluated as a possible remedy for the diminishing coverage associated with landline random digit dialing (RDD) surveys (Link et al. 2008; Link et al. 2009; Johnson and Williams 2010). Specifically, Blumberg and Luke (2011) report that persons living in over 45% of U.S. households have little or no chance of being contacted for a landline telephone survey. Yan, Zang, and

Zhao (2009) and Khare, Wouhib, and Singleton (2009) found that wireless-only and non-telephone households contributed to the undercoverage in the 2007 National Immunization Survey, a landline RDD survey designed to target households with children aged 19 to 35 months.

Operationally, a telephone survey that uses an ABS frame is a mixed-mode survey because addresses without a matching telephone number must be contacted by mail, the Internet, or in-person visit. Long et al. (2009) developed a dual-frame methodology based on ABS and landline RDD for the 2008 Massachusetts Health Insurance Survey. The departure from the sole use of RDD in prior versions of the survey was motivated by the concern that cell-only persons were much less likely to have health insurance than other persons. Data were collected using multiple modes—telephone, Web, and mail.

Barron (2009) found that the sequential nature of a mixed-mode survey based on ABS can result in data-collection periods that are double or triple that of an RDD survey. The amount of time needed to conduct a mixed-mode ABS survey is directly associated with the proportion of sampled mailing addresses with a viable telephone number. Although a request for a telephone number can be mailed to ABS households, Murphy, Harter, and Xia (2010) and Lutz et al. (2010) reported less than a 5% compliance rate. These experiences indicate that survey planners should instead rely on commercial vendors to provide telephone matching services for their ABS samples.

Telephone-match rates for ABS samples vary by location and type of mailing address. Blumberg and Luke (2011) report that the proportion of cell-phone-only households is significantly higher in metropolitan areas and in regions outside the Northeast. Lower match rates should be expected in these areas because most telephone-to-address matching is based on listed landline numbers' match rates. Using data collected in 2009 for the National Immunization Study, Amaya, Skalland, and Wooten (2010) reported that two commercial vendors were able to match at least one telephone number to approximately 74% of sampled mailing addresses. The initial match rates ranged from a high of 92.8% for apartments to a low of 9.6% for households whose only mailing address was a P.O. box. However, the high match rate for apartments was due to the linkage with a single telephone number associated with the building and not unique numbers associated with each HU. The results of a field verification indicated that approximately 53.4% of sampled addresses were correctly matched to a working telephone number.

Mixed-mode surveys can compensate for the undercoverage associated with a single mode. For example, Smyth et al. (2010) used ABS to sample households in a rural region by mailing them invitations and asking them to respond either by mail or on the Web. The results indicated that relying on the Web alone would have excluded potentially important segments of the population. When the Web results were supplemented with the mailed results, however, the results were quite similar to those obtained for the mail-only portion of the survey. This suggests a potential cost savings for researchers who have access to Web survey capabilities.

By contrast, Dillman, Smyth, and Christian (2009) and Griffin, Fisher, and Morgan (2001) recommend that the choice of multiple response options should be tempered by a potential reduction in response rates. For example, Han et al. (2010) describe an embedded mode experiment where half of an ABS sample was mailed a letter asking a household member to complete the questionnaire on the Web. The other half was sent a five-minute paper screener with no mention of the Web. Although the Web group was given the opportunity to respond on paper in the follow-up, the final response rate of 27.9% was still significantly lower than the 34.6% for the group initially assigned to the paper mode. Similarly, Messer (2009) reported that a Web-preference treatment with a $5 incentive and a mail follow-up resulted in a 46.3% response rate compared to a mail-only treatment with a $5 incentive, which produced a 56.7% response rate.

The decision to use a mixed-mode survey requires careful consideration of the trade-offs between coverage, nonresponse, and measurement error (Dillman, Smyth, and Christian 2009). In addition, multiple modes can create a plethora of ways that a sample member can potentially complete a survey. As a result, maintaining a control system to deal with the status of cases in the field is exponentially more complex than maintaining a unimodal design (Barron 2009). Researchers should be aware of the additional time and resources needed to design systems to support mixed-mode surveys.

Discussion

Once the exclusive realm of direct mailers, the use of residential mailing addresses now influences the development of sampling frames for surveys regardless of mode. This is not surprising, given that direct mailers and survey researchers both seek to "saturate" their respective target populations. Although the mailing address of nearly every housing unit in the United States can be found in either the CDS file or the CDS No-Stat file, the coverage afforded by these files depends largely on the mode of data collection.

The rapid acceptance of ABS for in-person surveys is motivated by the search for alternatives to the costly and time-consuming effort associated with traditional area sampling. Unlike mail surveys, which offer near complete coverage of the U.S. household population, in-person surveys require a locatable city-style mailing address so that interviewers can find the address in the field. Households with drop-point addresses may also be included if in-the-field sampling procedures are implemented to list and sample units within each drop point.

ABS provides a way to fill in the shrinking coverage associated with landline RDD. The use of ABS can hinder the quick turnaround feature of RDD because addresses that cannot be matched to a telephone number must be contacted via mail or visited in person. However, sampling methodologies that combine ABS with demographic and geographic data enable sophisticated multi-mode designs to be developed that could not be considered with RDD alone.

Recent reductions in the number of unlocatable mailing addresses (especially in rural areas) combined with frame supplementation techniques specifically developed for ABS have significantly improved the coverage of ABS for in-person household surveys. In addition, the recent availability of the USPS No-Stat file makes locatable addresses available for P.O. box throwbacks on rural carrier routes, and for approximately 6% of all drop units. Because some GQs have business addresses (e.g., private colleges), however, alternative data sources should be considered if adequate coverage of the GQ population is required.

In the future, the use of ABS is likely to be enhanced as the GPS coordinates of addresses become more accurate. Knowing the exact physical coordinates of a locatable mailing address would eliminate geocoding error; enable field interviewers to use GPS to find an address; and facilitate the use of monitoring techniques to detect interviewer falsification. Some vendors (e.g., Tele Atlas 2011) already offer exact coordinates for many addresses in the United States.

A challenge facing the future use of ABS for survey research is the rising tide of concern among the U.S. public regarding data privacy. A manifestation of this concern is apparent in a comprehensive U.S. data privacy bill (H.R. 5777) that was introduced in Congress in July 2010. This bill would expand restrictions on the collection or use of "sensitive" information to include such common demographic data as race, ethnicity, religious affiliation, and income (Fienberg 2010). If enacted, these restrictions could limit the appending of these data to an individual's mailing record. Such data facilitate the oversampling of a particular race or ethnicity, general income level, or religious affiliation.

In many ways ABS is not just a new tool in a survey researcher's toolbox; it's a whole new toolbox. A case in point is a new set of terminology heretofore unknown to most survey researchers. Knowing the nuances associated with terms like "simplified address," "drop point," or "geocoding error" is a prerequisite for the effective application of ABS.

As best practices for the use of ABS for surveys are developed, researchers will no longer be able to simply claim that the source of their ABS frame is the "USPS DSF." Instead, they should be proactive and ask their list vendors to provide documentation about the source of the address files they provide (e.g., DSF$^{2®}$ or CDS), what portion of same they are licensed to access, and what list hygiene they apply to their addresses. Additional care is needed if a vendor also selects the sample from an ABS frame, because vendors differ in their ability to draw probability samples from an ABS frame.

Survey methodology is in the midst of a revolution of communication technologies that are very different for the young and the old, for the rich and the poor, and for those in different languages and cultures (Conrad and Schober 2008). As a result, the way survey samples are designed and selected is changing at an unprecedented rate. ABS is sure to play an integral role in the development of these new methodologies.

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