A Review of Methods to Estimate the
Status of Cases with Unknown Eligibility

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As the American Association for Public Opinion Research (AAPOR) addresses in Standard Definitions (AAPOR, 2000), the calculating of response rates depends in part on estimating the proportion of cases of unknown eligibility that are in fact eligible. This rate is part of the formula for response rate 3 (RR3) and is designated as "e". Calculating "e" applies to all types of surveys, but has been of particular concern in random digit dialing (RDD) telephone surveys since a) response rates to RDD surveys have been falling, b) the number of calls needed to secure a given response rate has been rising, and c) despite equal or greater field efforts, the proportion of numbers with unknown status has been increasing (Brick et al., 2003; Murray et al., 2003; Piekarski, 1999; Piekarski, 2003; Son and Gwartney, 2003; Steeh et al., 2001).

This paper will examine 1) methods for calculating eligibility rates, 2) features of sample and survey design that influence "e", 3) actual estimates of "e" that have been calculated, and 4) using geographic information to examine eligibility. Attention will focus on the case of RDD telephone surveys since almost all of the literature deals with such studies.

Methods of Calculating Eligibility Rates

Several different methods have been proposed to calculate "e": 1) minimum and maximum allocation, 2) proportional allocation or the CASRO method, 3) allocation based on disposition codes, 4) survival methods either using a) number of calls only or b) number of calls and other attributes of phone numbers, 5) calculations of number of telephone households, 6) contacting telephone business offices, and 7) continued calling.

The minimum and maximum allocation method simply takes the cases of unknown eligibility and assumes that either 0% or 100% are eligible (Butterworth, 2001; Lessler and Kalsbeck, 1992; Lynn, Beerten, Laiho, and Martin, forthcoming; Smith, 2003). This is useful in determining the upper and lower bounds for the response rate. Under Standard Definitions the 100% eligibility assumption produces the minimum response rate (R1) and the 0% eligibility assumption yields the maximum response rate (R5). The limitation is that often the unknown eligibility level is so large that the possible range of response rates is great. In RDD national surveys the range is usually greater than 10 percentage points and can go as high as 25 percentage points (Lessler and Kalsbeek, 1992; Lynn et al., forthcoming, Montaquila and Brick, 1997; Nolin et al., 2000; Smith, 2003). When screening for a small sub-population is involved, the range can easily exceed 50 points (Ellis, 2000).

The proportional allocation or CASRO method assumes that the ratio of eligible to not eligible cases among the known cases applies to the unknown cases (Butterworth, 2001; Ellis, 2000; Ezzati-Rice et al., 2000; Frankel, 1983; Hidiroglou, Drew, and Gray, 1993; Lessler and Kalsbeek, 1992; Strouse, Carlson, and

Hall, 2003). It has the advantages of being easily calculated from information readily available from each individual survey and being conservative (i.e. producing a high estimate of the eligibility rate and thereby not inflating the estimated response rate). Its ease, availability, and conservative leaning is why it is the method used in AAPOR's on-line response rate calculator (www.aapor.org/default.asp?page=survey_methods/ response_rate_calculator).[1]

But its conservative nature is in effect a biased overestimate of the eligibility rate. It overestimates eligibility because it assumes that the unknown cases have the same attributes as the known cases, when the one fact that is known about the known and unknown groups is that they differ on the resolution dimension. Moreover, this method also assumes that the proportion eligible in the unknown group is unrelated to the number of calls or attempts made resolve the status of the unknown cases. Take the case of RDD surveys of households. Eligible cases (e.g. working, residential numbers) can be identified by contact attempts and more attempts identify more of them. Non-eligible cases that represent working, non-residential numbers (e.g. businesses) can be likewise identified by attempts. But non-assigned numbers with ringing tones can not be resolved by attempts and thus make-up a larger and larger share of unknown cases as the eligible and not eligible cases are identified and removed from the known category. Likewise, non-voice lines going to either residences or non-residences and used exclusively for computers, faxes, or other non-voice purposes have every little chance of being resolved by attempts and will also make up a larger share of the unknown group as other cases are resolved as eligible or ineligible. Thus, the proportion of eligible cases among the unknown cases will fall given more attempts to establish the status of telephone numbers. Most likely the greater the proportion of cases resolved, the less like the known cases the unknown cases will be and thus the greater the overestimate bias in the proportional allocation method (Frankel et al., 2003; Keeter et al., 2000; Sebold, 1988; Steeh et al., 2001).

Allocation based on disposition codes is used in various ways to calculate the eligibility rate. The simplest way uses disposition codes alone to determine whether a case is eligible or not (Behavioral..., n.d.; Ellis, 2000). For example, the Behavioral Risk Factor Surveillance System (BRFSS) surveys has about 14 final disposition codes for cases of unknown eligibility and assumes that those involving answering machines, quick hang-ups, technological barriers, and certain other circumstances are

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[1] Standard Definitions' basic admonition (2000, p. 36) is that "in estimating e, one must be guided by the best available scientific information on what share eligible cases make up among the unknown cases and one must not select a proportion in order to boost the response rate."

all eligible and those involving all ring-no-answers and/or busy signals are all not eligible (Behavioral..., n.d.). The problem with this approach is that there appears to be little or no empirical basis for the differential allocation and in the BRFSS case the differential allocation is extreme.[2]

A more advanced version takes the disposition status of the unknown cases (e.g. ring-no-answer cases vs. indeterminant-answering-machine cases) and estimates eligibility for each disposition based on disposition-specific, internal or external evidence.

Survival analysis methods use attempt-specific outcomes and the assumptions of standard survival analysis to estimate the proportion of cases eligible among the remaining unknown cases (Brick et al., 2002; Frankel et al., 2003; Strouse, Carlson, and Hall, 2003). The simplest method uses only the attempt-specific outcomes to calculate the survival curve and thus the eligibles among the remaining unknown cases. A more elaborate model partitions cases based on other known attributes such as whether they are a listed or unlisted number. This conditional approach then calculates survival analysis on the separate sub-groups and combines results for an overall eligibility rate (Brick et al., 2002).

Like the proportional allocation method, the survival analysis method only needs data regularly collected as part of a survey. However, it uses more information than the CASRO method utilizes and in theory should be better able to model and estimate the eligibility rate than the former method.[3] The limitations are that 1) it is uncertain how well the statistical assumptions of survival analysis (e.g. that telephone numbers are censored randomly) are actually met, 2) sample sizes used in the estimates may get too small with smaller samples or when much sub-setting is used, 3) it is a fairly complex statistical procedure to carry out, and 4) the application of survival analysis to this problem is relatively new and as Brick et al. (2002) note, "we have not yet had sufficient experience to adequately predict the conditions that result in unstable estimates." Similarly, Strouse, Carlson, and Hall (2003) express concern that estimates are "too sensitive to small changes in assumptions affecting the calculation of residency for unresilved cases under the survival method." The potential instability in the method is illustrate by the two examples reported by Brick et al., 2000. For the 1999 National Educational Survey the estimated eligibility rates were 21.1-24.2% (for respectively the general and conditional methods), but for the National Survey of America's Families (NSAF) it was 5.1%-5.8%.

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[2]On differences between answering machine cases and ring-no-answer and related cases see Brick et al., 2003.

[3]As Brick et al., 2000 describe in one set of circumstances the two methods produce identical estimates.

Different survey designs probably contribute to this large difference in estimates across the two surveys, but the magnitude of the differences in the estimated eligibility rates is problematic especially since the very low NSAF estimates have not been replicated in subsequent surveys (Brick, 2003).

Among the attributes of numbers that have proven to be most effective in distinguishing working from not working numbers are whether the numbers are listed or not and the final dispositions of the unknown cases (e.g. rings-no-answers vs. answering machines) (Ellis, 2000; Frankel et al., 2003; Shapiro et al., 1995). For example, Ellis (2000) found that 57% of resolved eligible cases were listed as were 47% of answering-machine unresolved cases and 12% of unresolved ring-no-answer/busy cases.

The calculation-of-number-of-telephone-households method compares estimates of the number of telephone households from an RDD survey to estimates of telephone households from other sources such as the Census, in-person surveys, and telephone companies and governmental communications agencies (Butterworth, 2001; Frankel et al., 2003). If the telephone survey produces an estimated number of telephone households lower than the external, benchmark standard, then one calculates how many of the unknown cases must be eligible cases to account for the shortfall of households. If the telephone survey produces an estimate equal to (or exceeding) the external figure, then none of the unknown cases are deemed to be eligible. This method depends on having a good, external standard and the proper calculation of sampling estimates. It also hinges on the sampling variances in the survey and external estimates and in smaller surveys in particular the former would be large.

Two methods that use survey-specific auxiliary information are the business-office and continued-calling approaches. Under the business office approach at end of or sometimes after the field period, local, telephone, business offices are contacted and asked the status of individual unknown numbers (Frankel et al., 2003; Groves, 1978; Haggerty, 1996; Massey, 1980; Massey, 1995; Montaquila and Brick, 1997; Nicolaas and Lynn, 2002; Nolin et al., 2000; Sebold, 1088; Shapiro et al., 1995; Smith, 2003; Strouse, Carlson, and Hall, 2003).

The chief advantage of this method is it offers the possibility of obtaining definitive, case-level information on the status of unknown cases. But the method has many limitations. First, it has appreciable extra costs and takes extra time since one must follow-up with either all unknown calls or a random sample of same with the telephone companies after the survey is completed. Second, it is possible to obtain information on only a sub-set of the unknown cases. Business offices will often decline to provide information about telephone numbers. As Table 1 indicates studies report that between 12% and 55% of the unknown cases could not be resolved by this method. The difficulty of obtaining information from business offices has led some researchers to abandon this approach (Groves and Kahn, 1979;

Wooley, Kuby, and Shin, 1998). Third, the method does not always yield accurate information. At best it tells one if a phone number pays a residential rate. This does not ensure that it is a voice line (Frankel et al., 2003) or that it is attached to an occupied household. For example, in Italy the level of non-contacts is strongly associated with the number of secondary houses in a region, thereby suggesting that many unanswered numbers are reaching unoccupied residences (Iannucci, Quattrociocchi, and Vitaletti, 1998). Also, the calls to business offices are usually carried out several weeks to months after the end of a field period. It does not appear that these follow-up calls have determined the status of phone numbers during the survey period (Sebold, 1995; Shapiro et al., 1995).[4] Finally, some studies have found that business offices often give out incorrect information about the status of numbers. For example, Shapiro et al. (1995) found that "in at least 38% of the cases in which the business [office] classified a number as residential when the survey classified it otherwise, the business office was wrong or the interviewer recorded the answer incorrectly...[and] (w)hen the business offices classified the number as nonworking at least 36% of their determinations were incorrect." However, it is unclear on what basis these judgments were made or how differences in time period were handled.

The second follow-up method is the continued-calling approach under which the unknown cases or a random sample of same are followed up with additional calls after the end of the field period (Frankel et al., 2003; Groves, 1978; Sebold, 1988; Sangster, 2003). As with the business-office approach, this has the advantage of potentially determining the status of individual cases. It also has some of the similar drawbacks. First, it is costly in time and money, especially if all cases or a large sample is followed up. Second, even allowing for dozens of additional calls over a long, follow-up period will not resolve many cases. As Table 1 shows, 17-83% of numbers were still unknown after the follow-up calls. Third, as far as can be told, the method has not been used to determine the eligibility of calls at the original status date, but rather at the point of eventual contact weeks or even months later. Strictly speaking this does not resolve the eligibility issue.

Of course these different methods can be used together. Either the different methods can be separately applied and their estimates compared (e.g. Brick et al., 2002; Butterworth, 2001; Frankel et al., 2003; Lynn et al., forthcoming; Montaquila and

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[4]As <u>Standard Definitions</u> (AAPOR, 2000) indicates, "Surveys should define a date on which eligibility status is determined. This would usually be either the first date of the field period or the first date that a particular case was fielded (AAPOR, 2000)." Thus, what the business office contact needs to determine is whether the number was eligible at the appropriate point in time.

Brick, 1997; Nolin et al., 2000) or two or more methods can be applied to produce a single estimate. For example, both follow-up calls and contacting business offices can be used to resolve unknown numbers. Also, after using one or both of the follow-up methods, one might estimate eligibility by proportional allocation to the remaining unresolved cases or by the minimum/maximum procedure (Nicolaas and Lynn, 2002; Smith, 2003). Similarly, partitioning cases by listing status could not only be used in survival analysis, but in follow-up or proportional allocation methods. For example, Ellis (2000) proposes an estimate in which the proportional allocation is separately applied for listed and unlisted cases.

Sample and Survey Design and Eligibility Rates

Several aspects of sample and survey design influence eligibility rate. Taking RDD surveys as an example, eligibility rates will be higher if a) the initial sample of numbers is pre-screened more extensively and/or b) fielded numbers are worked less extensively. Pre-screening efforts that will increase the eligibility rate include a) selecting blocks of numbers with more listed numbers in them, b) eliminating business numbers by cross-checking white and yellow page listings and dropping those that occur only in the later or by other database methods, and c) automatically pre-calling numbers for working tones (Battaglia et al., 1995; Brick et al., 2000; Brick et al., 2003; Piekarski and Cralley, 2000). During the field period, the eligibility rate for the unknown cases will fall as cases are worked for longer periods and with greater efficiency (Cunningham, Martin, and Brick, 2003; Frankel et al., 2003; Keeter et al., 2000; Sebold, 1988; Steeh et al., 2001). More calls, a longer calling period, and more effective calling (spreading calls across different days and different times) will all reduce the proportion of eligible number among the residual of unknown cases.

Estimates of "e" That Have Been Calculated

When the differences from the various methods described above are coupled with differences resulting from the design and execution of the survey design, the range in estimated eligibility rates is huge even if one ignores estimates under the minimum and maximum approach. Depending on how the remaining unknown cases are allocated, the follow-up methods produce estimates ranging all the way from 5% to 88% (Table 1), survival methods have yielded estimates of 5%, 6%, 20%, 24%, and 35% (Brick et al, 2002; Frankel et al., 2003), and other methods produced figures from 10% to 55% (Butterworth, 2001; Ellis, 2000; Keeter et al., 1998; Keeter et al., 2000).

As alluded to in the discussion of methods above, the proportional allocation method produces high, upwardly-biased estimates of "e". Follow-up methods also tend to yield fairly high

estimates, although this in large part depends on how the residual unknown cases are handled. The survival method tends to produce the lowest figures. In some instances the survival method produces sufficiently lower estimates than the follow-up methods do that one would have to assume a large overreporting of eligibility by the business-office and/or continued-calling approaches, underestimating by the survival analysis, or some combination of these. The former could be possible due to failure to reconcile time periods, misreporting from business offices, or misattribution of eligibility based on information from business offices. The latter could stem from underlying assumptions of survival analysis not being met.

Using Geographic Information to Understand Eligibility

Besides looking at the status of numbers by their telephone attributes (listed/not listed; number of listed numbers in the same block of numbers, reason for non-contact, etc.), they can also be examined by the geographic areas in which they are located and the attributes of those areas. Looking at area alone, unknown numbers in the US are more common in the Northeast and Pacific coast than in the South or Midwest (Montaquila and Brick, 1997; Nolin et al., 2000) and in Italy they are more frequent in areas with many secondary households (Iannucci, Quattrociocchi, and Vitaletti, 1998). Also, in the US they are higher in metropolitan areas in their own county and lowest in non-metropolitan counties (Montaquila and Brick, 1997; Nolin et al., 2000; see also Steeh et al., 2001). Unknown numbers are also higher in areas with more educated people, wealthier areas, places with more renters, and neighborhoods with fewer children (Montaquila and Brick, 1997; Nolin et al., 2000).[5]

The higher unknown rate for different areas will mean, all others things being equal, that these areas will be under-represented in the realized sample. This might be due to there being fewer eligible numbers per sampled numbers, to a lower response rate, or some combination of these factors. The former would be more the case if the unknown case were predominately not eligible and the later if they were uncontacted, eligible households.

Summary

While there are several useful ways to estimate the status of unknown cases to calculate "e", each has notable limitations. The minimum-maximum method typically produces a very wide range in estimated response rates; the proportional allocation method overestimates "e" and thus underestimates response rates; follow-

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[5]Of course telephone number portability will undermine the use of geographic data tied to phone numbers.

up methods are time-consuming and expensive, usually do not take time into consideration, and for that and other reasons, may rest on inaccurate data or wrong inferences from the available information; telephone household estimates may be too imprecise due to sample variance and imperfect external standards, and survival analysis rests on unproven assumptions and perhaps unstable data. At present none can be considered a gold standard for the calculating "e". As a result, researchers should use multiple methods to estimate "e" and ultimately calculate the response rate and report a range in the later when estimates of "e" vary.

In addition, existing methods can be improved. The follow-up methods would greatly benefits from a) taking time into consideration in establishing eligibility and b) more careful and circumspect use of the information obtained from telephone companies. In addition, telephone companies have much more information on phone numbers than they have been willing to share and the business-office method would greatly benefit if telephone providers would be willing to share more information under conditions that would maintain privacy (e.g. by making certain assessments themselves following assignment rules created by survey researchers). Survival analysis needs to be applied to more surveys so its robustness can be better judged and should be tested against criterion data (e.g. can survival analysis accurately estimate eligibility rates in a survey of 100% known cases when only results from the first half or two-thirds of outcomes are used in the survival analysis?).

Even with triangulation and improved techniques, there will be no simple answer to what "e" is. There is no general eligibility rate that can be applied to all or even most surveys. The eligibility rate will depend on aspects of sample and survey design and execution and will have to be calculated separately for each and every survey. Still, surveys with comparable designs and executions should produce similar estimates of "e" so that some design-specific, expected rates might eventually be determined. This might allow for some to adopt a reasonable estimated "e" when their surveys do not have their own estimates of "e" from follow-up methods or other approaches.

To improve our understanding of "e" and therefore of response rates, more research is needed. One useful tack would be a meta analysis comparing techniques across a large number of studies. A second study design would involve collecting detailed information from in-person surveys on the number and use of telephones and telephone-related technologies (modems, faxes, call screening devices, etc.) within households. Another promising approach would involve specially designed collaboration studies between survey researchers and telephone companies in which complete, detailed, accurate, and timely information going well beyond the partial, limited, questionable, and dated information now available from business offices about the unknown telephone numbers would be provided by the cooperating phone companies so that the status of

all unknown numbers could be determined. Through these and other research designs a more thorough understanding of "e" can be obtained.

Table 1

Studies of the Eligibility of Cases of Unknown Eligibility

Study	Method	# of Calls before Follow-up	Time before Follow-up	Eligible	Not Eligible	Still Unknown	N
1	CBO	11	1-4 weeks	28%	35	36	294
2a	CBO	12	--	--	95%	--	20
2b	CBO	17	--	53%	47	--	32
3a	AC	--	4 weeks	40%	40	20	266
3b	AC	20	up to 6 mos.	38%	44	17	239
4	CBO	20	1-3 weeks	44%	34	22	41
5a	CBO	11	3 mos.	18%	70	12	14624
5b	CBO	--	2 mos.	37%	48	15	124
6	CBO	14	--	10%	67	23	163
7a	CBO	10	--	23%	22	55	530
7b	AC	10	3 weeks	5%	12	83	530
8	AC	--	3 mos.	6%	16	78	708
9	CBO	14	1+ mos.	41%	--	--	600

CBO=Contact business office
AC=Additional calls

Studies: 1=Massey, 1981; 2=Groves, 1978; 3=Sebold, 1988; 4=Haggerty, 1996; 5=Shaprio et al., 1995; 6=Nicolaas and Lynn, 2002; 7=Frankel et al., 2003; 8=Sangster, 2003; 9=Brick and Broene, 1997

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