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D R A F T

Sampling frames and master samples [*]

by

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[**] The views expressed in this paper are those of the author and do not imply the expression of any opinion on the part of the United Nations Secretariat.

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Chapter Three: Sampling frames and master samples*

A. Sampling frames and their development

1. One of the most crucial aspects of sample design in household surveys is its frame. The sampling frame has significant implications on the cost and the quality of any survey, household or otherwise. In household surveys faulty sampling frames are a common source of *nonsampling* error, particularly under-coverage of important population sub-groups. There is, therefore, a need to elaborate best practices in frame construction and usage taking into account various stages of sampling. This section covers issues on frames and their development with emphasis on multi-stage sample design.

3.1. Definition of sample frame

2. A simple definition of a sampling frame is the *set of source materials from which the sample is selected.* The definition also encompasses the purpose of sampling frames, which is to provide a means for choosing the particular members of the target population that are to be interviewed in the survey. More than one set of materials may be necessary and this is generally the case in a household survey because of its multi-stage nature. The early stages of selection in household surveys are typically drawn from *area* frames while the last stage may be selected either from an area or *list* frame (see subsections below on area and list frames).

3.1.1. Sample frame and target population

3. An important consideration in deciding upon the appropriate frame(s) to use for household surveys is the relationship between the survey target population and the unit of selection. It is the latter that determines the frame. It should be noted also that the unit of selection is what determines the probability of selection at the last stage

- ***Example***

To illustrate, a survey whose target population is infant children might consider as potential frames either medical facilities recording births within the past 12 months or households whose occupants include infants under 12 months old. In the first instance the frame comprises, first, the list of hospitals and clinics and, second, the list of infants born in those facilities. The units of selection are the medical facilities at the first stage and infants at the second stage. Thus, the unit of selection and the target population are synonymous terms for the final selection stage. In the second instance, however, the frame would likely be defined (in a latter stage of selection) as a list of households in small areal units such as villages or city blocks. In applying the sample plan households would be selected and screened to ascertain the presence of children under 12 months old. In this case, the household is the unit of selection upon which the probability of selection is based, even though members of the target population is not actually identified and surveyed until the households are screened for their presence.

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4. In household surveys – the subject of this handbook – the unit of selection and around which the sample design is based is the household. Yet the target population, even in a general-purpose survey, will differ depending upon the measurement objectives and, except for household income and expenditure surveys, will usually be a population other than the household itself. Examples are employment surveys where the target population is generally persons 10 (or 14) years old or older, thus excluding young children altogether; surveys on reproductive health of women where the target population is women 14-49 years old (and often only ever-married women in that age group); etc.

3.2. Properties of sampling frames

5. As we discussed above the sampling frame must of course capture, in a statistical sense, the target population. Beyond that, a perfect sample frame is one that is *complete*, *accurate* and *up-to-date*. These are ideal properties that are unattainable in household surveys. Nevertheless it is essential to strive for them either in constructing a frame from scratch or using one that already exists. The quality of a frame may be assessed in terms of how well its idealized properties relate to the target population. Recall that our definition of a probability sample – one in which every member of the target population has a known, non-zero chance of being selected – is a useful barometer for judging a frame's quality.

6. The degree to which there is failure to achieve each of the ideal properties produces survey results that are biased in various ways, but often in the direction of *under-estimating* the target population.

3.2.1. Completeness

7. The ideal frame would be complete with respect to the target population if all of its members (the *universe*) are covered by the frame. Frame coverage is therefore an essential feature in judging whether it is suitable for a survey or, if not, whether it can be repaired or further developed to make it suitable. In the previous example, infants born at home or other places outside medical facilities would not be covered in the survey if medical facilities were used as the sole frame for sampling. Hence, in this example there are significant numbers of the target population that have a zero chance of inclusion in the sample, and the condition for a probability sample is violated. As a result, an estimate of the number of infants would be under-stated by the facility frame. Moreover, the characteristics of infants would likely be quite different from those born at home and, so, the facility frame would yield biased distributions for important indicators about the infants or their care.

8. Inadequate coverage is also a potential problem in household surveys. For example, a national survey plan may be intended to cover the entire population through a household survey yet the survey team decides to exclude various segments such as persons living in institutions, nomadic households and boat people. In such a case coverage of the total population is obviously not attainable through the household survey. Additional frames would have to be developed to cover the excluded, non-household groups mentioned in order to give their members a non-zero probability of being included. Failing that, the target population should be

more carefully defined so that users are clearly informed of which segments of the population are excluded from coverage.

3.2.2. Accuracy

9. Accuracy is an important feature as well in household surveys, although inaccuracies are more likely to occur in frames other than those used for surveys. A frame can be said to be accurate if each member of the target population is included once and only once. A simple illustration is the case of a list of some kind that contains errors. An example would be a list of business establishments defined as those employing more than 50 workers. Errors could occur if (1) any establishment on the list had 49 or fewer workers, (2) any establishment with 50+ workers was missing from the list, or (3) an establishment was listed more than once (perhaps under different names).

10. In household surveys it is less likely to encounter such inaccuracies in the frame. Some examples however would be the following: (1) a frame consisting of a computer file of enumeration areas, *EA*s, that is missing some of its elements, (2) a list frame of households in a village that is missing some of those living on the perimeter of the village, (3) a list frame of households in an areal unit where some of the households are listed in more than one unit and (4) an old list frame of households that does not include newly constructed dwellings. The latter is also an example of a frame that is not current, discussed further below.

11. Missing *EA*s or listed households within an areal unit mean of course that the affected households have no chance of being selected for the sample, again violating the condition for a true probability sample. Duplicate listings also violate the probability criterion unless they are known about so that the true probabilities of selection can be calculated. Unfortunately, omissions and erroneous duplicates of the types mentioned are often not known, so that the sampling technician may be unaware of the need to correct the frame before sampling from it. On the other hand, a few omissions or duplicates in a frame will not usually cause any appreciable, or even noticeable, nonsampling bias in the survey estimates.

3.2.3. Current frame

12. Ideally of course a frame should be current in order for it to fulfill the other two properties of completeness and accuracy. An obsolete frame obviously contains inaccuracies and is likely to be incomplete, especially in household surveys. The quintessential example of a frame that is out of date is a population census that is several years old. The old census will not accurately reflect new construction or demolition of dwellings, in- or out-migrants in dwelling units, births or deaths. These deficiencies violate the criterion of a probability sample that each member of the target population must have a *known* chance of selection.

- ***Example***

Suppose the frame consists of *EA*s defined according to the most recent census, which is 4 years old and no up-dating of the frame has been done. Suppose further that numerous squatter areas have built up on the outskirts of the capital city in *EA*s that were, at the time of the census, either empty or virtually empty of population. The sample design would give no chance of inclusion to

households living in the formerly empty *EA*s, thus violating the probability sample conditions. In *EA*s that were virtually empty another serious problem arises even though those *EA*s do not technically violate probability sampling requirements. The sample would undoubtedly be selected using *pps* with the *MOS* being the census population or household count. By virtue of its having very little population at the time of the census, any high-growth *EA* would have only a slight chance of being selected when *pps* sampling is used. As a result the sample could have an unacceptably high sampling variance.

3.3. Area frames

13. In this subsection and the next we discuss the two categories of frames that are used in sampling, whether for household surveys or other applications. It is important to note that in a multi-stage design the frame for each stage must be considered as a separate component. The specific frame is different at each stage. The sample design for a household survey will likely use both an area frame, discussed in this subsection, for the early stages and a list frame, next section, for the last stage.

14. In household surveys an area sampling frame comprises the geographical units of a country in a hierarchical arrangement. The units are variously labeled, administratively, from one country to another but typically include such terms, in descending order, as province or county; district; tract; ward and village (rural areas) or block (urban areas). For census purposes administrative sub-divisions are further classified into such entities as crew leader areas and enumeration areas or *EA*s. Often the census *EA* is the smallest geographical unit that is defined and delineated in a country.

15. For survey purposes there are four distinct characteristics of geographical units that are important for sample design, as follows:

a. The geographical units cover, usually, the entire land area of a nation.
b. Their boundaries are well-delineated.
c. There are population figures available for them.
d. They are mapped.

16. Coverage of the totality of the nation's geographic area is important, as we have noted, because it is one of the criteria for achieving a bona fide probability sample. Well-delineated boundaries that are mapped are invaluable in sample implementation because they pin down the locations where field work is conducted and help the interviewer locate the sample households. Population figures are needed in sample design to assign measures of size and to calculate the probabilities of selection.

17. The usual starting point in development of an area frame for household surveys is a country's population census – for the four reasons cited above. In addition the *EA* is a conveniently-sized geographical unit to select in the latter stages of sampling (the penultimate stage in a two-stage design). In most countries *EA*s are purposely constructed to contain roughly equal numbers of households – often about 100 – in order to provide comparable workloads for census-takers.

18. An area frame is, paradoxically, also a *list* – because one must begin with a list of the administrative, geographic units of a population to select the early stages of a household survey sample. This leads to the discussion of list frames.

3.4. List frames

19. A list sampling frame is quite simply a frame made up of a list of the target population units. Theoretically, a list frame for household surveys exists for every country just after its census is taken. The fresh census provides, in principle, a geographically arranged listing of every household – or dwelling unit - in the country.

20. A newly completed census list is ideal as a household sampling frame because it is as current, complete and accurate as any household list could ever be. Because of its geographical arrangement it is fairly simple to stratify it for proper geographical distribution of the sample. A follow-up sample survey, to obtain more detailed or supplemental information than the census can efficiently provide, conducted just after the completion of a census is thus ideally suited to use of the list frame that is briefly available at that time. Obviously, the longer the interval between the census and the follow-on survey the less useful the census listings would be as the frame source.

21. There are other examples of lists that might be considered as appropriate sampling frames for household surveys depending upon their quality. One is a civil registry. Another is a register of utility connections. Civil registries would be candidates for frame use in countries where careful records are kept of its citizens and their addresses. In some instances they may be more useful than an area-based census frame, because the registry may likely be continuously up-dated. Utility – usually electricity – connections may be useful as a sampling frame whenever a country's census is seriously obsolete. It would of course have to be evaluated to assess potential problems and their impact such as the number of households not having access to power or electrical hook-ups servicing multiple households.

22. Another list frame that is widely used in developed countries is a register of telephone subscribers. Sampling is done through *random digit dialing* (*RDD*) techniques to ensure that subscribers with unpublished telephone numbers have their proper chance of being selected. *RDD* sampling is not recommended, however, in countries that have low penetration rates for telephone ownership.

23. In a conventional household survey the last stage of selection is, invariably, based on a list frame concept. We have discussed previously how the penultimate design stage may yield a sample of clusters in which a current listing of households is compiled and from that list the sample households are selected. Thus we have an area frame defining the sample clusters but a list frame defining the sample households within the clusters.

3.5. Multiple frames

24. In the preceding chapter we discussed two-phase sampling in household surveys involving the use of screening techniques to identify a particular target group in the first phase followed by a second-phase interview of a sub-sample of those identified. Another sampling technique that may accomplish much the same end result is to use more than one sampling frame. Usually this involves only two frames, in which we have a *dual-frame* design, but occasionally three of more frames may be used (*multi-frame* design).

3.5.1. Typical dual frame in household surveys

25. For simplicity of presentation we will discuss dual-frame designs though the principles are analogous for multi-frame designs. In general the methodology entails combining a general-population area frame with a list frame of persons known to be members of the particular target population under study – for example, an unemployment survey based on an area frame of households supplemented with a list-frame sample of currently unemployed persons that are registered with the social services ministry. The objective is to build up the sample size with persons that have a very high probability of being in the target population, which can be a cheaper and more efficient alternative to two-phase sampling. It is necessary to use the general-purpose household frame to account for target population members who are not on the list; in the example they would comprise unemployed persons not registered with social services.

26. There are several disadvantages, however, with dual-frame designs. One is that the list-frame must be very current. If a large percentage of persons selected from the list have had a change in status that removes them from the target population, then use of the list frame is inefficient. In our example any unemployed person that has become employed by the time the survey is conducted would be ineligible, which illustrates why the list frame must be up to date.

27. Another disadvantage is that persons on the list frame will likely reside in dispersed locations throughout the community and it is costly to interview them due to travel. That of course is in stark contrast to the area-based household frame where the sample can be selected in clusters to reduce interviewing costs.

28. A serious issue with dual-frame designs is that of duplication. Generally, persons included on the list frame will also be included on the area frame. Again in our example, unemployed persons selected from a registry are members of households of course, and so they would have a duplicate chance of selection. The potential for duplication has implications for the content of the survey questionnaire in order to adjust for it properly. In our example each unemployed person interviewed in the household sample would have to be queried as to whether he/she is registered with the ministry on its list of unemployed. For those that respond in the affirmative, further work is necessary to match their names with the list-frame, a process that is error-prone and fraught with complications. When a successful match is found the survey weight of the person affected must be changed to $(1/P_h + 1/P_l)$ to reflect the fact that she has a probability, P_h, of being selected from the household frame and P_l of being selected from the list frame. It is important to note that matching must be done against the entire list frame and not just those on the frame that happened to have been selected in the sample. This is because the

probability (and weight) is a function of the chance of selection irrespective of whether actual selection occurs.

3.5.2. Multiple frames for different types of living quarters

29. Another type of dual-frame sampling occurs when the target population resides in different kinds of living quarters that are non-overlapping. For example, a survey of orphans would most likely be designed to include orphans living in institutional arrangements such as orphanages as well as those living with a surviving parent or other relatives in households. The dual-frame design would consist of a household frame plus an institutional frame and they are of course non-overlapping.

30. The objective of a design of this type is to cover the target population adequately (as close to 100-percent as possible). When significant numbers of the population live in each of the two types of living quarters, significant biases would occur if the sample were restricted to only one of the frames. A sample of orphans, for example, based only on those living in households would not only yield an underestimate of the population of orphans but a biased estimate in terms of their characteristics; similarly for a survey exclusively based on orphans living in institutions.

31. The disadvantage discussed above regarding duplication does not pertain to designs from dual, non-overlapping frames. For that reason they are significantly less difficult to administer.

3.6. Typical frame(s) in two-stage designs

32. In the previous chapter we emphasized the practical value of two-stage sample designs. This subsection discusses the frame that is typically used in two-stage designs.

33. The geographical units – clusters – that comprise the first stage of selection are often defined as villages (or parts of villages) or census *EA*s in rural areas and city blocks in urban areas. The frame consists, then, of all the geographical units that make up the universe of study however defined – the nation as a whole, a province or set of provinces or the capital city. Sampling is done by compiling the list of units, checking it for completeness, stratifying the list in an appropriate fashion (often geographically) and then selecting a systematic sample of the units, the latter usually by *pps*.

34. If the file of clusters in the universe is very large there may have to be intermediate, dummy stages of selection, as previously discussed. In that case the frame units are defined differently for each of the dummy stages. In the earlier example for Bangladesh the frame units for the two dummy stages were defined and thanas and unions.

35. The second-stage frame units in a two-stage design are simply the households in the first-stage sample clusters. When they are sampled from a list of households the frame is, by definition, a list frame. They may also be sampled as compact segments (see previous discussion in chapter 2, subsection 2.7.3) created by sub-dividing the clusters into geographical parts that are exhaustive and mutually exclusive. In that case the second-stage frame is an area frame.

3.7. Master sample frames

36. Here we just briefly mention the concept of a master sampling frame, which is discussed in considerable detail in section B below.

37. A master sample frame is one in which the frame is used to select samples either for *multiple* surveys, each with different *content*, or for use in different *rounds* of a continuing or periodic survey. The sampling frame itself does not vary either from one survey to the other or from one round to another of the same survey. Instead – and this is its distinctive characteristic – the master sample frame is designed and constructed to be a stable, established aspect for selecting the sub-samples that are needed for particular surveys or rounds of the same survey over an extended period of time.

3.8. Common problems of frames and suggested remedies

38. Problems of nonsampling bias arise in household surveys when the sampling frame is obsolete, inaccurate or incomplete. In the great majority of national, general-purpose surveys the basic frame is the most recent population census and that is the frame that is assumed in the remainder of this subsection. Problems of obsolescence, inaccuracy and incompleteness often occur together in census-based frames and they tend to increase in magnitude as the interval between the census and the survey increases.

39. We have mentioned that a frame must be current in order to reflect the current population; and that one based on, say, a 5-year old census does not adequately account for population growth and migration. Even a current census frame can be incomplete and cause problems vis-à-vis household surveys if it does not cover military barracks, boat people, nomads and other important sub-populations that do not live in traditional household arrangements. Inaccuracies in both current and old census frames pose problems in a variety of ways such as those arising from duplicate household listings, missing households or those enumerated or coded to the wrong *EA*.

40. Appropriate strategies for dealing with old, inaccurate or incomplete census frames depend in part on (1) the objectives of the survey and (2) the age of the frame. Regarding measurement objectives if a survey is purposely designed, for example, to cover only immobile households a census frame that excluded nomadic households would suffice; on the other hand, a procedure would have to be developed to *create* a frame of nomadic households if the survey was intended to cover them. In that respect, whether a census frame is complete or not depends on the definition of the target population, or sub-populations, to be covered by the survey.

41. Remedies to cope with problems of obsolescence and inaccuracies would differ depending on how old the census is. While it may not be prudent to offer a precise rule, owing to varying national conditions, a rule-of-thumb to guide an appropriate strategy for frame revamping or up-dating would be whether the census is more than two years old. As for inaccuracies of the type mentioned two paragraphs above, remedies given in subsection 3.8.2 are applicable.

3.8.1. Census frame more than two years old

42. The first situation applies to countries with old censuses - two years old or more. It is these old frames that present the biggest challenge in household survey sample design, especially in rapidly growing cities. Complete, countrywide up-dating of the old census frame is the ideal because, if successful, it assures that the resulting survey data are both as *accurate*, in terms of survey coverage, and as *reliable* as possible. Unfortunately, it is also the most expensive and time-consuming and, therefore, impractical. Still, there may be no alternative in those countries where the census is seriously obsolete.

43. Instead of complete up-dating a compromise would be to up-date the frame only in targeted areas, the latter identified by country experts familiar with growth patterns and demographic shifts. What is needed to up-date the census frame is fairly simple - *a current MOS*. For purposes of frame up-dating, the *MOS* would be defined as the number of dwelling units, as opposed to the number of households or persons.

44. It is important to recognize that the *MOS* does not need to be precise in order for the sample methodology to be valid. For example, if a given *EA* was thought to have 122 households on the basis of the last census, we would not be concerned if it currently has 115 or 132. For that reason it is not useful to attempt frame up-dating in old, established neighborhoods that are little changed over decades, even though individual inhabitants come and go. Instead, what is of concern is when the current situation is drastically different from the last census – say, 250 households when 100 were expected. Such situations are likely in neighborhoods of heavy growth or demolition, such as squatter communities on the city fringes, high-rise development sites or demolition sites. Such areas would constitute the target areas for up-dating. We would rely upon country collaborators and experts to help identify the target areas and, of course, include only those where the changes are post-censal.

45. Up-dating would entail several steps including (a) identification of the *EA*s that make up the targeted areas, (b) a quick-count canvass of the affected *EA*s to obtain a current *MOS* and (c) revision of the census file to show the up-dated *MOS*. As mentioned an approximate *MOS* is sufficient, which is why the quick-count canvass operation should be done to identify dwelling units rather than households; in doing so, it is not necessary to knock on doors in order to count dwellings except, possibly, in multi-unit dwellings where the number of units is not apparent without entering the building.

46. Up-dating old census frames in the manner described above would be necessary to stabilize the probabilities of selection for the penultimate stage units and, hence, the reliability of the survey estimates. Practically, the up-dating helps control not only the overall sample size but also the listing and interviewing workloads of the field staff. Moreover, it decreases the likelihood of encountering large clusters in the field that turn out to be much bigger than anticipated and having to sub-sample them or take some other appropriate action. Related to the last point is the fact that sub-sampling requires weighting adjustments – a complication in data processing – and that potentiality would be diminished to the degree that no unexpectedly large clusters are encountered *after* sample selection at the penultimate stage.

47. Given that the standard sample design for a household survey will likely entail compilation of a *current* listing of households in the sample clusters, up-dating at that stage of selection would also occur (see reference to *ppes* sampling, which applies here as well, in following subsection). While the current listing for sample clusters that were not up-dated may resemble closely the census lists (though this is not guaranteed), it would be expected that sample clusters from the up-dated portion of the census frame would yield current listings that would be significantly different from the census – both in the total number of households and in their specific identification.

48. One final point needs to be made about using an old census and this concerns sample validity rather than sample variance. Since clusters are usually selected with probability proportionate to size, failure to up-date the MOS for high-growth clusters in advance of sample selection would mean serious under-representation of areas that had small numbers of households in the census but have since grown significantly from squatters or new construction. Survey results would be biased and of course misleading, since the characteristics of persons living in such high-growth areas are likely to be quite different from those in more stable neighborhoods.

3.8.2. Census frame two years old or less

49. This subsection applies to those countries that have comparatively recent censuses conducted within the past year or two and do not need general up-dating. In those cases clusters would be selected using the original census *MOS*, since the latter would be expected to be quite accurate from the recent census. Updating per se would only take place at the penultimate stage of selection when field staff undertakes a current listing of households in the sample clusters. The sample households would be selected from the current listings and sampling weights would be adjusted, as necessary, in accordance with the procedures discussed in section 2.6.2 with respect to *ppes* sampling.

50. While a few clusters in the frame universe may have grown substantially since the census was completed, the number of such cases would not be expected to be so large as to significantly affect either field operations or survey precision. Any such clusters that happen to fall into sample could be sub-segmented if necessary. Sub-segmentation, or "chunking", as it is known, is a field procedure intended to lessen the listing workload. The procedure involves dividing the original cluster into sections, usually quadrants, selecting one at random for listing and selecting the households to be interviewed from that segment. Sub-segmentation does not improve sampling reliability because each sample chunk would carry an extra survey weighting factor equal to the number of chunks in the cluster – a factor of 4 if the cluster is divided into quadrants. Sub-segmentation does help, however, in containing field costs. The need for chunking can occur, even though the census is recent, again in high growth *EA*s that are drastically changed since the census. With a very recent census of course, it is expected there would be very few such areas.

51. It should be noted that the types of inaccuracies that were previously mentioned (duplicate or missing households, erroneous *EA* assignments) are partially corrected when up-

dating that entails fresh listings of households in the penultimate stage is carried out. That of course is another strong reason to obtain current listings of households in surveys.

B. Master sampling frames

52. Master samples can be cost effective and efficient when a country has a sufficient number of independent surveys or periodic rounds of the same survey to sustain their use. It is perhaps self-evident that they be properly designed but it is also very important that they be properly maintained over time. The reader is urged to refer to *Sampling Frames and Sample Designs for Integrated Household Survey Programmes*, a document in the technical series published in 1986 by the UN Statistical Division under its National Household Survey Capability Programme (NHSCP). That report provides a much more comprehensive treatment of master sample frames and their uses than is presented in the following subsections.

3.9. Definition and use of a master sample

53. The sampling frame (or frames) for the first stage of selection in a household survey must cover the entire target population. When that frame is used for multiple surveys or multiple rounds of the same survey it is known as a *master sample frame* or, simply, a *master sample*.

54. Use of a master sample frame should be considered by any country that has a large-scale, continuing, intercensal household survey programme. There are economies of scale in using the same frame units over time because much of the costs of sampling is absorbed in the developmental operations of the master frame rather than each time a survey is fielded. On the other hand countries that conduct only an occasional national survey between population censuses would not benefit appreciably from utilizing a master sample design.

55. The features of a master sample deal with the number, size and type of units at the first stage of selection. In general a master sample consists of an initial selection of primary sampling units (*PSU*s) that remain fixed for each subsample. Note that the latter stages are usually variable. For example, in the final stage of selection the particular households that are chosen for interview are usually different for independent surveys, while they may be the same or partially overlapping in repetitive surveys.

3.10. Ideal characteristics of PSUs for a master sample frame

56. The principles that govern the establishment of a master sample frame are little different from those for sampling frames in general. The master frame should be as complete, accurate and current as practicable. A master sample frame for household surveys is typically developed from the most recent census, just as a regular sample frame is. Because the master frame may be used during an entire intercensal period, however, it will usually require periodic and regular up-dating such as every 2-3 years. This is in contrast to a regular frame which is more likely to be up-dated on an ad hoc basis and only when a particular survey is being planned.

57. The features that are conducive to the development of a master frame are, likewise, similar to those for sampling frames generally. In defining units to use as the *PSU*s, for example,

a constraining factor is that they should be areal units that are already mapped. This is not a severe constraint, however, since the frame units will invariably be defined as administrative units already constructed for the census. An important feature that may differ from regular sampling frames, however, is that the size of the *PSU*s must be sufficiently large to accommodate multiple surveys without interviewing the same respondents repeatedly. Even this feature, however, can be relaxed in certain applications.

- ***Example***

A particular kind of master frame that has been used in some settings is based on a two-stage design. The first stage is a large sample of *EA*s (or similarly small and mapped areal units). A sub-sample of the master *EA* sample is selected for each independent survey that utilizes the frame. Each sub-sample is listed or otherwise sub-segmented for the survey application at the time the latter is actively planned. To illustrate further, the master sample may be 10,000 *EA*s, of which 1000 are sub-sampled for an employment survey. A household listing is undertaken in the 1000 *EA*s from which a second-stage sample of 15 households in each *EA* is chosen for the survey. The following year, another sub-sample of 800 *EA*s is selected from the master sample to be used in a health survey; and so on. In this way no *EA* is used more than once, so the size of the *PSU* is irrelevant.

58. The size of the *PSU* is important, however, when all the sub-samples generated by the master frame must come from the same set of *PSU*s; in the example above, *EA*s are the *PSU*s and a different subset of *EA*s is used in each sub-sample. When the former is the case, the design cannot be two stages but must be three or more. The method of sample selection of the *PSU*s in a master sample is not particularly an issue because they would be selected in the same way whether from a master sample or not. Generally the method would be by probability proportionate to size, *pps*, except in some rare cases where the *PSU*s are more or less equal in size; in the latter case, an equal probability sample of *PSU*s could be used.

3.11. Use of master samples to support surveys

59. In subsection 2.2.7 it was discussed how a large sample is needed for master samples in order to provide enough households to support multiple surveys over several years without having to interview the same respondents repeatedly. The anticipated sample sizes for all the proposed and potential surveys that may utilize the master sample frame are key parameters in designing its framework. For example if it is anticipated that 50,000 households would be interviewed in the various surveys to be served by the master sample, the sampling team would have the basic information it needs to decide on the number and size of *PSU*s. Moreover, a plan of survey implementation can be developed in terms of its use of the master sample, as shown in the following example (see also the illustration in subsection 2.2.7 for comparison):

- ***Example***

As in the example of 2.2.7 the master sample in Country A comprises 50,000 households. Three planned surveys will have sample and cluster sizes as follows: 16,000 households, 6 households per cluster for the income and expenditures survey; 12,000 households, 12 per cluster for the labour force survey; and 10,000 households, 20 per cluster for the health survey. The different cluster sizes are chosen to ameliorate the differential effects of *deff*. In addition, there are 12,000

households to be held in reserve for other surveys if needed. The three planned surveys imply a total number of 4167 *PSU*s (16000/6 + 12000/12 + 10000/20). Since the content of the surveys that might use the reserve sub-sample is unknown, it is decided to plan on a cluster size of 12, which adds another 1000 *PSU*s for a grand total of 5167. The master sample design team decides therefore to construct a master sample of 5200 *PSU*s. The definition of the *PSU* must take account of the number of households to be interviewed. In this illustration each *PSU* must be large enough to yield 50 households for interview, that is, 6 + 12 + 20 + 6. With this information, the sampling team can then determine which geographical unit best serves to define the *PSU*s. If Country A has *EA*s that average 100 households with little variation around that average, then it would make sense to use *EA*s as the *PSU*s.

3.11.1. Advantages of multiple use of a master sample frame

60. There are distinct advantages to using the same *PSU*s in a master sample programme. First and foremost a field staff can be organized and maintained for the life cycle of the master sample. For example, interviewers can be hired, trained and available at the beginning of a master sample programme when it is known where the *PSU*s are located for all surveys that are to use the frame for, say, 10 years. To the extent necessary the interviewers can be hired locally from residents in or near the master sample *PSU*s. Second, survey materials such as *PSU* maps and household listing sheets can be generated at the start of the master sample programme, thus saving time as well as amortizing a significant portion of survey operating costs over all the anticipated surveys. Again it is important to emphasize, however, that such benefits only accrue when the master sample is to be heavily utilized.

61. Other advantages to master samples in general, whether utilizing the same *PSU*s in a three-stage design or different *PSU*s in a two-stage design, include (1) the potential for integrating data, analytically, from two or more applications of the master sample using different content and (2) the potential to respond quickly to unforeseen data collection needs.

3.11.2. Disadvantages of multiple use of a master sample frame

62. There are some disadvantages to a master sample such as the possibility of exhausting the *PSU*s, that is, running out of households if the master frame is over-utilized. This, however, may be forestalled through adequate advance planning. Although it is not plausible to foresee all the uses that may be made of a master sample throughout its life cycle, reserve sub-subsamples can be designated for possible use so long as the master sample is big enough.

63. Another disadvantage is an ever-increasing amount of bias that accrues when appropriate up-dating is not carried through as the master sample ages. Finally, master samples are not well-suited to provide data on "special requirement" surveys such as those for particular provinces or rare sub-populations that may be of interest.

3.12. Allocation across domains (administrative regions, etc.)

64. Government statistical offices have been under increasing pressure to tabulate and analyze their household survey data for important sub-national administrative areas such as

major regions, provinces and large cities. Some countries such as Vietnam are even expected to routinely provide data at the district level. These requirements and expectations are driven by legitimate policy needs, generally on the grounds that socioeconomic programmes are focused on and developed for local areas as opposed to the nation as a whole.

65. In the parlance of statistical sampling these are *domain* estimates, previously discussed in subsection xxx. They come at a heavy cost because the sample sizes necessary to achieve reliable results are enormous and often beyond the survey budgets that governments can generally muster. The need for domain data also affects the development of a master sample frame.

66. Considerations of how many domains to establish and of what type were discussed in section 2.2.4 on sample sizes and will not be repeated here. Once those decisions have been made the master sample frame can be constructed. As an example, one country may decide that surveys under its master sample programme are to provide data for only two domains – urban and rural. Another country with 12 provinces may want to provide estimates for each of them and decides that its survey resources can support the extra sample sizes needed if the provinces are treated as domains. A third country with 50 provinces may decide that it is too costly to produce estimates for each of them but instead decides to define as domains the 8 major geographic regions into which the 50 provinces are divided. A fourth country may decide not to establish domains per se but instead tabulate its proportionately-allocated national sample by region, province, urban, rural and for selected large cities, intending to release to the public those sub-areas for which the sample size is deemed large enough to give reasonably reliable results.

67. For the last example in the preceding paragraph domain allocation is not relevant because the sample is proportionately distributed among the sub-national areas of interest. For the first three of the examples special steps must be taken to allocate the master sample *PSU*s appropriately. Since domain estimation implies equal reliability for each of the sub-population groups or areas defined as a domain, the same number of sample *PSU*s should be selected in each domain – a requirement that pertains irrespective of whether the sample design is based on a master sample or not.

3.13. Maintenance and updating of master samples

68. In terms of its effect on population coverage proper maintenance of a master sample frame is a key element in its development and in planning for its use. The master sample of a given country is typically used for the decade between censuses, during which time far-reaching shifts in population movement are likely to occur. It is necessary to up-date the frame periodically to reflect population changes so that it will continue to be "representative."

69. Two types of up-dating are important. First, and this is the simplest to achieve, is to prepare new listings of households in the sample clusters selected at the penultimate stage. That procedure is generally recommended throughout this handbook, whether for master samples or single-use sample designs. In doing so, the sample clusters are automatically up-dated to reflect migration, births and deaths. This type of up-dating, confined to the sample clusters, helps to

minimize coverage (nonsampling) error but the sampling variance increases over time unless the entire frame is up-dated.

70. There is also the need to periodically up-date the entire frame to properly account for postcensal growth on a large scale such as that which occurs in high-rise residential construction and expansion of squatter areas in cities. The *EA*s in which such high-growth takes place are invariably much smaller at the time the master sample frame is constructed. As a result, their measures of size become seriously understated as growth takes place. Thus their chances of selection in a *pps* design are minimized. The effect on the sampling variance can be drastic when such *EA*s do happen to be selected, because the current *MOS* may be larger than the original by orders of magnitude.

71. Problems of high-growth areas and their effect on master samples can be ameliorated significantly by revising the frame regularly, say, every 3 years. Refer to subsections 3.8.1 and 3.8.2 for more discussion on methods of up-dating frames.

3.14. Rotation of master samples of PSUs

72. The reader is referred to subsection 2.8.2, "Sampling to estimate change or trend," in chapter 2 for a detailed discussion of the issue of sample overlap in connection with repetitive or continuing surveys intended to measure change or trends. Overlapping samples imply using a scheme of utilizing replacement households when surveys are repeated. One method of replacement is sample rotation, which provides for partial overlap from survey to survey or occasion to occasion.

73. In the aforementioned subsection it was pointed out that both sampling reliability (desirable) and nonsampling error (undesirable) are greatest when the same households are used in each survey round. As a result a compromise is usually sought by using partial overlap in the sample from one round to the next, especially when a survey is repeated three or more times; see subsection 2.8.2 for the rationale of partial overlap.

74. One method of introducing partial overlap is to replace or rotate the sample *PSU*s (as opposed to replacing the households within the sample *PSU*s). When there is a master sample of *PSU*s used not only for rounds of the same survey but for multiple surveys it is equally important to consider carefully the need to rotate them.

75. In order for a rotation plan to be feasibly implemented and to give meaningful results the degree of overlap between time periods should be the same and constant through time. For example, if the overlap between year 1 and year 2 is k percent, then it should also be k percent between year 2 and year 3, between year 3 and year 4, and so on. Accordingly, when entire *PSU*s are rotated this feature needs to be integrated into the rotation design.

3.15. Country examples of master samples

76. In this subsection we present descriptions of master samples in four developing countries – Cambodia, United Arab Emirates, Vietnam and Mozambique. Each illustrates some of the

features and principles of master sampling such as one or two-stage sampling of master sample units and flexible application for particular surveys that are discussed in this chapter. In addition other features of sample design that are highlighted in the handbook are illustrated. These include, *interalia*, implicit stratification and optimum choice of cluster size to reduce the effects of *deff* and sample allocation for domains.

Cambodia 1998-99

77. The master sample of Cambodia illustrates the use of a two-stage design where a large sample of *PSU*s supplies a master list of second-stage area segments that are sub-sampled for use in particular surveys.

78. Cambodia's National Institute of Statistics developed a master sample in 1999 to use in the Government's intercensal household survey programme that consists of a periodic Socio-Economic Survey and, potentially, surveys on health, labour force, income and expenditures, demography and ad hoc surveys. The 1997 population census served as the frame for design of the master sample which was carried out in two phases. The first phase was a *pps* selection of the *PSU*s, defined as villages with the measure of size being the census count of households. Selection of the *PSU*s was performed as a computer operation, while the second phase entailed creation of area segments within the selected *PSU*s, which was a manual operation.

79. It was decided to use villages as the *PSU*s because they are large enough, on average (245 households in urban areas and 155 in rural), to have enough households to accommodate several surveys during the intercensal period, without the burden of repeatedly interviewing the same respondents. The alternative of using census *EA*s was considered but discarded because they are only half the size of villages on average. Special populations that are transitory or institutionalized were not included in the master sample, nor were military barracks.

80. A total of 600 *PSU*s was selected in the master sample because it was felt that number would give enough spread throughout the country to represent all the provinces adequately. Implicit stratification was used in selecting the sample, effectuated by sorting the village file in geographic sequence - urban-rural by province, district and commune. Thus the master sample was proportionately allocated, automatically, by urban-rural and by province.

81. An interesting feature of the master sample in Cambodia was the second phase of the sampling operation. As mentioned this entailed creating area segments within the selected *PSU*s. Note here that the second *phase* of master sample construction is not to be confused with the concept of second *stage* of sample selection, the latter of which pertains to selection of households for particular surveys. Within each selected master sample *PSU*, area segments of size 10 households (on average) were formed through a clerical task as an office operation. In that context it did not entail any field work except in unusual cases, because the 1997 census listing books and existing sketch maps were used. The number of segments created within each master sample *PSU* was computed as the number of census households divided by 10 and rounded to the nearest integer. For example a village containing 187 households per the 1997 census was divided into 19 segments.

82. The segments, so created, constituted the building blocks to be sampled or sub-sampled in connection with the application for particular surveys. Selection of one or more segments from all, or a subset of, the *PSU*s is done for each survey or survey round that utilizes the master sample. Note that creation of the master sample as described above affords the opportunity for each of the particular surveys which utilize it to be self-weighting, depending upon the details of their sample designs.

83. A key advantage of the master sample design is that it affords much flexibility in terms of how it is sub-sampled for use in particular surveys. Selection of the clusters (that is, segments) for each survey can yield a *different* set if desired. The typical *PSU* contains about 18-30 segments, providing an ample number of segments in each *PSU* to sustain all surveys. Moreover, repetition of the Socio-economic Survey on an annual basis is possible with a different set of segments every year. Alternatively, sample overlap is also possible by retention of some of the segments (say, 25 percent) from year-to-year in a pattern of rotation, where 75 percent of the segments are replaced each year.

84. A disadvantage of the master sample design is the use of compact clusters (all the households in the sample segment are adjacent to each other), which increases the design effect somewhat over non-compact segments, that is, a systematic sample of households within a larger cluster. It was thought the design effect would be ameliorated to some degree by limiting the cluster size, however, which is the reason segments of only size 10 households were settled upon.

85. It was anticipated that up-dating of the sample would take place every two or three years. Although it was recognized that it is better to up-date the entire master sample, it was decided to up-date only in the *PSU*s for the particular sample survey being planned at that time. Up-dating consisted of field visits to prepare a new listing of households in the affected segments. The same *land area* in those segments that contained the original set of households was re-listed, one reason why the segment boundaries are so important.

86. Another interesting note about the Cambodian master sample is the cooperation that was sought from village headmen in up-dating operations. They are known to maintain careful registers of all the households in their villages and, moreover, the registers are routinely kept current. Their listings in most instances are thought to be quite accurate. In addition the village headmen were also invaluable resources in terms of identifying and locating the land area appropriate to any particular segment.

United Arab Emirates 1999

87. The master sample of UAE illustrates a master sample design that employs special stratification to cope with its two diverse populations – citizens and non-citizens – and how the standard segment design (see subsection 2.7.2) can be exploited to deal with the issues of varying *EA* sizes and an old census.

88. UAE's master sample is described by the Ministry of Planning as a super sample of 500 *PSU*s based upon the 1995 population census as its sampling frame. It is intended to be used for

particular household surveys until the next population census is undertaken. The *PSU*s are defined as census *EA*s, or parts thereof, such that, on average, a *PSU* contains about 60 households - both citizen and non-citizen.

89. Two strata were constructed prior to selection of the *PSU*s. The first consisted of enumeration areas in which one-third or more of the households were citizen households at the time of the census. The second stratum is all other enumeration areas. A total of 1686 enumeration areas were classified in stratum I and 2986 in stratum II. Using systematic selection with probability proportionate to size, a sample of 250 *PSU*s was selected in each of the two strata for a total of 500 *PSU*s nationwide. It was expected that this master sample would yield approximately equal numbers of citizen households and non-citizen households. A new, current listing of households was undertaken in the 500 *PSU*s to bring the frame up to date, after first segmenting large *PSU*s (those with 90 households or more) and selecting one of the segments randomly within each such large *PSU*. The listing operation resulted in approximately 30,000 households in the sample *PSU*s to be utilized in various combinations for particular surveys. To facilitate flexible application, the households in each sample *PSU* were divided into 12 subsets, or panels, of an expected 5 households each.

90. A noteworthy feature of the master sample is that it is not self-weighting because the two strata are of unequal sizes. The first survey to utilize the master sample was the 1999 National Diabetes Survey, sponsored by the Ministry of Health. Others that were expected to be fielded include a labour force survey and an income and expenditure survey (or family budget survey).

91. Certain special circumstances in UAE dictated how the master sample design was constructed. Two overriding considerations that were carefully taken into account were the target populations and the sampling frame.

92. There are two important target populations in the country - citizens and non-citizens. While the former constituted about 43 percent of the population, according to the 1995 population census, they comprise only about *one-quarter* of the nation's households because non-citizen households are much smaller in terms of number of persons per household. The implication for sample design is that if a *proportionate* sample of the nation's households were selected nearly three-quarters of the responding households would be non-citizens. It further implies that the reliability of the resulting survey estimates for non-citizen households would be about 3 times better than that for citizen households. As the results were to be used to develop policy and plan programmes, such a disparity in the reliability of the estimates was not thought to be desirable or useful. The solution, in terms of sample design, was to treat the two disparate and unequal target populations as separate entities through application of proper stratification described three paragraphs above.

93. Another level of stratification was used as well. This was geographic stratification to ensure appropriate distribution of the sample by emirate and by urban-rural. The file of *EA*s was sorted in the following sequence prior to sample selection: first for the citizen stratum by urban, and within urban by emirate and within emirate by *EA* codes arranged in ascending order by the percent citizen, followed by rural, emirate and *EA* code; then the non-citizen stratum in the same sequence.

94. It was recognized that a key feature of a master sample frame is a clear set of maps that delineate the area units to be designated as the sample areas, that is, the *PSU*s. The area units had to be small enough to be conveniently listed but, at the same time, large enough so that they could be clearly defined with respect to natural boundaries (for ease of location). Census enumeration areas were thought to be the only feasible area units that met these dual criteria. Unfortunately, maps were not used in the population census, and hence the existing enumeration areas were not clearly defined in terms of known boundaries. As a result it was necessary to ensure that good boundary information be developed for the master sample *PSU*s (*EA*s).

95. Preparations for the master sample of *PSU*s made use of the "standard segment design," a methodology which has been used successfully in many countries through both the Demographic and Health Surveys programme and PAPCHILD (Pan Arab Survey of Maternal and Child Health).

96. It was decided to use the standard segment design because census enumeration areas in UAE are quite variable in size. Standard segments of approximately 60 households were created. The number of standard segments was calculated in each sample *PSU* as the total number of households (that is, citizen plus non-citizen) divided by 60 and rounded to the nearest integer.

97. For cases where the number of segments, that is, the measure of size was 2 or more, the *PSU* was divided into area segments. This required a field procedure in which a visit to the *EA* (*PSU*) was made and a sketch map was prepared using quick-counting and map-spotting of the dwellings (not the households). After segmentation one segment was chosen from each *PSU* at random, and that segment became the *actual geographic area* for sampling in the master sample. Another visit to the field was made to obtain a current list of the households in each sample segment, a procedure thought to be a vital component of the sampling operation in order to bring the 3-year old master sample frame up to date.

98. The final operation for the master sample consisted of subdividing the newly listed households in each sample segment into 12 systematic subsets or panels. One or more of the panels were to be used for particular surveys. Since the average size of the segment was about 60 households, each panel contains 5 households on average.

99. The main reason for having 12 panels was because of the flexibility this number provided in forming combinations for use in surveys. The actual choice for a given survey depended on various factors including the objectives of the survey, the desired cluster size and the overall sample size required for the survey. For example, two-fifths of the *PSU*s were to be used in the National Diabetes Survey; 4 of the 12 panels of households within those *PSU*s were included. This combination yielded an overall sample plan of 200 *PSU*s with clusters of size 20 (that is, 4 times 5 households) and a total sample size of approximately 4000 households.

Vietnam 2001

100. The master sample of Vietnam has two distinguishing features. It demonstrates use of two stages in selecting the master sample and a third stage when applied to particular surveys. Secondly, it demonstrates how a master sample can be allocated to geographic domains.

101. The master sample is based on the 1999 census as the sampling frame and is a two-stage design. *PSU*s were defined as communes in rural areas and wards in urban areas because it was decided that a minimum of 300 households would be necessary in each *PSU* to serve the master sample. Alternatively, *EA*s were considered as *PSU*s but they were too small and would have had to be combined with adjacent *EA*s in order to qualify satisfactorily as *PSU*s, a task which was thought to be much too tedious and time-consuming. The number of communes/wards, on the other hand, that had to be combined because of their small size was only 529 of the more than 10,000.

102. A total of 3000 *PSU*s was selected by *pps* for the master sample. Each sample *PSU* contained, on average, 25 *EA*s in urban areas and 14 in rural areas. For the second stage of selection three *EA*s were selected in each sample *PSU,* using *pps*. The second-stage units, *EA*s, contain an average of approximately 100 households according to the 1999 census – 105 in urban areas and 99 in rural areas.

103. An objective of the master sample was to be able to provide fairly reliable data for each of Vietnam's 8 geographical regions. Sample selection was undertaken independently within each province; thus, provinces served as strata for the master sample. It was desired to over-select the sample in certain small provinces that contain very small populations. Accordingly, the allocation of the sample among provinces was made by the method of *ppvs*, or probability proportionate to the square root of the size of the province. Proportional allocation between urban and rural areas was used.

104. In addition to the provincial-level stratification mentioned above, implicit geographical stratification within provinces was used. In applying the master sample to specific surveys, subsets of the *EA*s were to be used – for example, one-third of them for the Multi-purpose Household Survey. For survey applications a third stage of selection is administered in which a fixed number of households is selected from each sample *EA*. That number may vary by survey and by urban-rural. For example, 20 households per *EA* might be chosen for rural *EA*s and 10 per *EA* for urban ones.

Mozambique 1998-99

105. The master sample of Mozambique illustrates a case in which a single-stage selection of PSUs was selected to be used for all of the government-sponsored, national surveys in the nation's intercensal household survey programme. It also illustrates how a flexible master sample can be adapted to meet the measurement objectives of a particular survey.

106. Master sample *PSUs* in Mozambique were defined and sampled in a straightforward way as described in various parts of this handbook. The *PSUs* were constructed from the 1997 Population Census as the sample frame. They consist of geographical groupings of, generally, 3-7 census *EAs*, the latter of which contain about 100 households on average. The master sample *PSUs* were selected using probability proportionate to size, or pps, sampling.

107. A total of 1511 *PSUs* was selected to provide the framework for sampling to apply against Mozambique's integrated system of household surveys. The master sample *PSUs* were divided into panels, each comprising a systematic subset and therefore constituting a probability sample in its own right. There are 10 such panels of about 151 *PSUs* each. In the 5-Year (2000-2004) Plan, the Core Welfare Indicator's Questionnaire (CWIQ)[1] that was conceived by the World Bank was the first survey to make use of the master sample.

108. The sample plan for QUIBB was designed to obtain the relevant indicators necessary to profile the well-being of persons and households in Mozambique and to provide reliable estimates of these indicators at the national level, for urban and rural areas separately and for each of the 11 provinces in the country. The sampling methodology for QUIBB utilized the Mozambique master sample to choose about 14500 households in a stratified, clustered design. Accordingly, the first stage of selection was of course the master sample *PSU*s.

109. The second stage of selection for QUIBB was a sub-sample of the master sample *PSUs*. A total of 675 *PSUs* was sub-sampled from the 1511 in the master sample. They were selected systematically with equal probability and, moreover, equally allocated among the 11 provinces of Mozambique. At the third stage a sample of one enumeration area was selected in each of the QUIBB *PSUs.* Thus there are 675 clusters in the QUIBB sample – 475 rural and 200 urban. The enumeration areas were selected with equal probability because their sizes are roughly the same – as mentioned above, about 100 households on average, though there is variability. The final stage of selection occurred following field work in which the Instituto Nacional de Estatistica (INE) visited the clusters to compile a fresh list of households to bring the 1997 sample frame up to date. From the lists so compiled, a systematic sample of 20 households in rural areas and 25 in urban was selected for the QUIBB survey interviews. Sample selection for QUIBB was thus a four-stage selection process, although the master sample upon which it was based was a single stage.

110. Two design features for QUIBB illustrate the flexibility with which the master sample can be adapted to fit the particular requirements for a survey application.

111. First, in utilizing the master sample for QUIBB there was interest on the part of INE to use the aforementioned panels that had already been designated. With the desire to have about 600 *PSU*s for QUIBB it was hoped that 4 of the panels could be used. The idea was discarded, however, when it was realized that the number of panels that would be necessary for QUIBB would be different for each province, since the measurement objective required more or less the same sample size by province. Instead, the 675 *PSU*s necessary for QUIBB were selected

[1] The Portuguese acronym is QUIBB (Questionario Indicadores Basicos Bem-Estar) and that term is used to refer to the survey in this document.

systematically from the entire master sample file without regard to panels. This departure from the original intent of the master sample arose because equal reliability was wanted at the provincial level for QUIBB whereas the master sample was designed to provide a proportionate sample by province since national level estimates were expected to take precedence when the latter was conceived and designed.

112. A second important issue regarding the QUIBB sample design was the cluster size. It was agreed that the cluster sizes should be different for urban and rural households on the grounds that the sample design effect, or *deff*, is more severe in rural areas where most of the economic livelihood is subsistence farming. In other words, each household in a rural area was likely to have very similar characteristics. The master sample afforded the possibility of selecting a different fixed number of households (25 and 20 respectively in urban and rural areas) in the final stage.

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