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LONGITUDINAL FAMILY AND HOUSEHOLD ESTIMATION IN SIPP

by

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1. INTRODUCTION

Many types of statistics will be produced by the Survey of Income and Program Participation (SIPP), but there is one type that was the driving force behind the unique design of the survey. To be fully successful, SIPP must tell us what happens to households over the course of time. From it we must obtain estimates of the patterns of income receipt, program participation, and labor force participation at the household and family level by a host of other characteristics. Of particular interest are parameters such as total annual household income and the number of families that have stopped drawing food stamps by demographic characteristics.

Before estimates can be produced, a decision must be made on the definition of a longitudinal household to be used in this survey. (To simplify the presentation, we will concentrate our discussion on longitudinal households as opposed to longitudinal families. However, parallel longitudinal estimation procedures can readily be developed for families). It often happens that the occupants of several housing units move and regroup. We need to know which, if any, of the resulting households are to be considered continuations of the previous households. Many definitions have been proposed, but final agreement has thus far not been achieved. Also decisions have yet to be made on whether households that form or dissolve during a time interval of interest are to be considered as part of the universe for estimation purposes. Because of the absence of agreement in these areas, several proposed definition and universe combinations will be considered in this paper. They are listed in Section 2. Also because of this absence of agreement, the major aim of this paper will be simply to compare several possible longitudinal household estimation procedures and present criteria for choosing among them, without attempting to reach a conclusion on a preferred procedure.

We foresee several steps in the process of producing longitudinal households estimates. The focus in this paper, except for the final section, is the first step, the production of weights that would yield unbiased estimates assuming there are no data that are missing or in error, and that the frame coverage is perfect. Several procedures for obtaining such weights will be presented in Section 3. In Section 4 some numerical examples of the weights produced by these procedures are given. Choosing among these procedures is complicated by the fact that even assuming perfect response, data needed to produce unbiased estimates will be missing for some households because they are not collected with the current field procedures. This difficulty is principally due to the fact that, except for a few household definitions, all unbiased procedures assign positive weights to some longitudinal households for time periods when they are not in sample. The severity of this problem and the extent to which it is correctable in the future by changing field procedures or by modeling the missing data, vary by procedure. This problem, along with descriptions of other important features, both positive and negative, that estimation procedures may possess is presented in Section 5. This is followed in Section 6 by a detailed comparison of the features of the estimation procedures under consideration in this paper. Finally, in Section 7 we briefly discuss adjustments to the unbiased weights. It is anticipated that the two major components of such adjustments will be a procedure for adjusting for missing data, and a method for controlling key variables to independent estimates, such as CPS estimates.

It is assumed in this paper the reader has a basic knowledge of SIPP, including the design of this survey. Nelson, McMillen, and Kasprzyk (1984) provides this information.

2. LONGITUDINAL HOUSEHOLD DEFINITIONS

In this section four possible longitudinal household definitions are presented to illustrate the longitudinal weighting procedures that will be described in the next section. A thorough discussion of longitudinal household definitions is presented in McMillen and Herriot (1984). In addition, several other terms will be defined, including the longitudinal household universes considered in this paper.

Since household composition and data for SIPP are obtained on a monthly basis, each of the definitions to be presented will be in terms of household continuity from one month to the following month. A longitudinal household over a time interval of n (≥ 2) months is then defined to be one which is continuous for each of the n-1 corresponding pairs of consecutive months. (It has not yet been decided if this approach will actually be used in SIPP.)

For each of the definitions below the conditions for which household B at month t+1 is the continuation of household A at month t are stated. One condition that we require that all the definitions share is that A and B are either both family households or both non-family households. The other conditions are:

No Change Definition (NC). A and B have the same household members.

Same Householder (SH). A and B have the same householder. As an alternative, householder could be replaced by principal person in this definition without altering any of the statements made about it in subsequent sections, provided the final estimation procedure in Section 3 is also modified accordingly. (The householder of a household is, roughly, the person who owns or rents the housing unit. The principal person is the wife in a married-couple household, and the householder in all other households.)

Reciprocal Majority (RM). The majority of individuals who are both household members of A at time t and in the universe at time t+1 are members

of B at time t+1, and the majority of individuals who are both household members of B at time t+1 and in the universe at time t are members of A at time t. (This type of longitudinal definition was originally developed by Dicker and Casady (1982) for use in the National Medical Care Utilization and Expenditure Survey (NMCUES).)

Shared Experiences Definition (SE). Either conditions (1.a, b) or (2.a-e) presented below are satisfied.

(1.a) A and B are nonfamily households with the same householder, including single person households.

(b) At least 1/2 the members of A are members of B.

(2.a) A and B are family households.

(b) The householder or spouse of the householder of A is the householder or spouse of the householder of B.

(c) A and B have at least two members in common.

(d) If another household A' when substituted for A in (2.a-c) satisfies these conditions, then the number of household members common to A and B is more than the number common to A' and B.

(e) If another household B' when substituted for B in (2.a-c) satisfies these conditions, then the number of household members common to A and B is more than the number common to A and B'.

Some variation of this last definition is currently the leading candidate to be chosen as the SIPP longitudinal household definition.

We will now clarify several other terms.

A household is said to be in existence over a time interval of $n \geq 2$ months if it is longitudinal over that time interval. Its period of existence is the longest such time interval. In the case of a household which is defined cross-sectionally for a month t, but is not longitudinal over either of the two

month intervals containing t, then the period of existence of the household is defined to be one month.

If t_1 and t_2 are any pair of months, and longitudinal estimates are to be made over the interval $[t_1, t_2]$, then the following two possibilities will be considered in subsequent sections for the universe of households for which estimates will be produced.

Restricted Universe. The set of all households in existence over the entire interval $[t_1, t_2]$.

Unrestricted Universe. The set of all household in existence for one or more months in $[t_1, t_2]$.

Each sample panel is interviewed eight times. Each of the eight rounds of interviews takes four consecutive months to complete and is known as a wave.

Finally, we define an original sample person to be a person that was in sample during the first wave and will be at least 15 years of age by the end of the panel.

3. UNBIASED WEIGHTING PROCEDURES

In this section we present five weighting procedures for computing estimates of totals or proportions for longitudinal households that would be unbiased in the sense that the expected value of the estimator over all possible samples is the parameter of interest assuming no data are missing or in error, and perfect frame coverage. Modifications and adjustments of these estimation procedures necessary because of the unrealistic nature of these assumptions will be considered in Section 7. Except for the Continuous Household Members procedure, which will only be applied to the restricted universe, all the procedures will be stated for the unrestricted universe. To apply them to the restricted universe simply zero weight each household which is not in continuous existence over the time interval of interest.

Furthermore, unless otherwise stated, all the procedures will be applied to all four longitudinal definitions defined in Section 2.

First we will explain why a common method of estimation, weighting by the reciprocal of the probability of selection is not feasible for our purposes, and hence the need to consider alternative procedures. Let $X = \sum_{i=1}^{N} x_i$ be a parameter of interest, where x_i is the value of the characteristic for i-th unit in a population of size N. Typically in survey work, to estimate X a sample would be drawn in such a manner that the i-th unit has a known positive probability p_i of being chosen, and X would then be estimated by

$$\hat{X} = \sum_{i=1}^{N} w_i x_i \ , \tag{3.1}$$

where

$$w_i = \begin{cases} \dfrac{1}{p_i} & \text{if the i-th unit is in sample,} \\ 0 & \text{otherwise.} \end{cases} \tag{3.2}$$

Unfortunately for household and family estimation in SIPP, both cross-sectionally and longitudinally, such an estimation approach is not practical. For example, cross-sectionally a household is interviewed and used in the estimation process for a given month if and only if at least one household member is an original sample person. Consequently, to use (3.1) and (3.2) as an estimator it would be necessary to determine the probability that at least one member of the current household is an original sample person. It would be operationally impossible to determine this probability, since it would first be necessary to determine the first wave households for all current household members and then compute the probability that at least one of these first wave households was selected.

Fortunately though, it is not necessary that w_i satisfy (3.2) in order that (3.1) be unbiased. In fact if w_i is any random variable associated with the i-th unit in the population satisfying

$$E(w_i) = 1, \tag{3.3}$$

then (3.1) is unbiased, that is $E(\hat{X}) = X$. Thus, defining unbiased longitudinal household and family weighting procedures reduces to defining random variables w_i satisfying (3.3).

Before we present the longitudinal weighting procedures we will state what, for purposes of this paper, a cross-sectional household weight is, since most of longitudinal weighting procedures will be defined in terms of cross-sectional weights. The first wave cross-sectional weight for a sample household is taken here to be the reciprocal of the probability of selection. For all nonsample households in the universe this weight is defined to be zero. For any month after the first wave a different definition is necessary because of possible changes in household composition. So, the cross-sectional household weight for any such month is defined to be the mean of the first wave cross-sectional household weights for all persons in the household that month who will be at least 15 years of age by the end of the panel and who were in the universe during the first wave. This type of weighting procedure is currently being used in SIPP to produce cross-sectional estimates, hence the name. It is readily verifiable that the weights satisfy (3.3).

We also will leave it to the reader to verify that the weights for each of the longitudinal procedures to be presented satisfy (3.3) and hence lead to unbiased estimators.

Beginning Date of Household Procedure (BH). Each longitudinal household receives a single weight valid for any time interval that contains at least part of the period for which the household existed, namely the cross-sectional

weight for the household at the beginning date of the household. In particular, if there were no original sample persons in a household at its beginning date then its longitudinal weight would be zero. This approach to longitudinal household estimation was previously used in the NMCUES (Whitmore, Cox and Folsom 1982).

Beginning Date of Time Interval Procedure (BI). Each longitudinal household receives a longitudinal weight valid for all time intervals with the same beginning date, namely the cross-sectional weight for the household at the beginning date of the time interval. Longitudinal households that form during the time interval are assigned the cross-sectional weight for the household at its beginning date, as in the preceeding procedure.

Continuous Household Members Procedure (CM). The following procedure will only be applied to the restricted universe, as defined in Section 2. For any time interval for which the household is in existence the longitudinal weight to be assigned is determined by the set of persons that are members of the household throughout the time interval. The longitudinal household weight is the cross-sectional weight that would be assigned to a household consisting of this set of persons; that is, the average of the first wave weights of these people. A longitudinal weight of zero is assigned to the household if there are no original sample persons who are members throughout the time interval. The procedure is slightly biased because a longitudinal household with no members continuously present throughout a time interval has no chance of receiving a positive weight, thereby making satisfaction of (3.3) impossible. Since we believe this situation will rarely occur, at least for the longitudinal household definitions considered here, we expect this bias to be very small.

Average Cross-Sectional Household Weight Procedure (AW). Each longitudinal household receives a longitudinal weight valid for a specific time

interval, namely the average of the monthly cross-sectional weights for the household over the intersection of the life of the household and the specified time interval.

Note, there are many procedures, like AW, that entail the averaging of weights, both household cross-sectional weights and person longitudinal weights. We will examine only one of these procedures here, as an example of this type of longitudinal household weighting procedure.

Householder Weight Procedure (HW). The following procedure will be applied only to the No Change and Same Householder Definitions, since it is appropriate only for definitions that allow for a single householder during the household's existence (Generalizations of this procedure which are not so restricted in their applicability exist but will not be considered here.) The procedure assigns a single weight valid for any time interval that contains at least part of the period for which the household existed, namely the first wave cross-sectional household weight of the householder's first wave household. A longitudinal weight of zero is assigned to the household if the householder was not an original sample person.

As will be seen in Section 5, this procedure is clearly the one of choice when the Same Householder Definition is used. If that type of definition is used with householder replaced by principal person then a similar modification of this estimation procedure with householder replaced by principal person would be appropriate.

4 . EXAMPLES

In the following examples, the cross-sectional weight for the second and subsequent waves will be as defined in Section 3. The longitudinal household definition for procedures BH, BI, CM, and AW will be the reciprocal majority rule, as given in Section 2. For procedure HW, the longitudinal household definition will be the same householder rule, as given in Section 2.

In these examples a divorced mother (householder) with two children (both older than 14) residing with her has her widowed mother move into her house in December, 1983. In August, 1984 her widowed mother remarries and the new husband moves into the house at that time. In April, 1985 one of the children leaves the household. The longitudinal household weights will be determined for the three procedures for the following time periods:

A. the entire year 1984;

B. the entire year 1985;

C. the entire years 1984-85.

This will be done in each case for the following two scenarios:

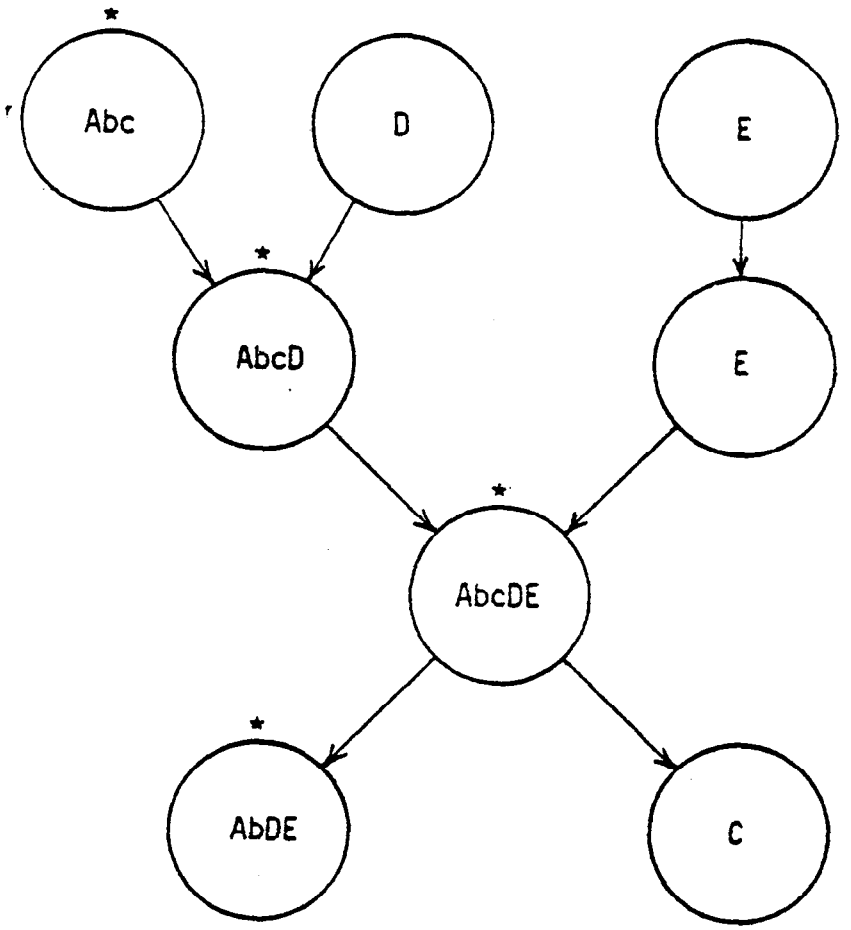
1. the new husband of the widowed mother was the only original sample person in the 1984 SIPP panel (originally interviewed in October, 1983-rotation group 1), with a first wave weight of 8,000;

2. in addition, the divorced mother and her two children were original sample persons (rotation group 1), each with a first wave weight of 4,000.

The six time period, scenario combinations will be denoted by A.1, A.2, B.1, B.2, C.1 and C.2.

Note: We chose to determine the weights only for the longitudinal household that continues through the entire 1984-1985 period, which is marked with an asterisk above it. The other longitudinal households can also be weighted with all these procedures, except CM which applies only to the restricted universe.

Below is a schematic diagram of the example



A = divorced mother

b = c = divorced mother's child

D = divorced mother's widowed mother

E = widowed mother's new husband

Let W_{C1} = cross-sectional weight under scenario 1
W_{C2} = cross-sectional weight under scenario 2

Procedure BH

A.1., B.1., C.1. = W_{C1} for Abc = 0

A.2., B.2., C.2. = W_{C2} for Abc = 4,000

Procedure BI

A.1., C.1. = W_{C1} for AbcD = 0

B.1. = W_{C1} for AbcDE = (1/5) x 8,000 = 1,600

A.2., C.2. = W_{C2} for AbcD = (3/4) x 4,000 = 3,000

B.2. = W_{C2} for AbcDE = (3/5) x 4,000 + (1/5) x 8,000 = 4,000

Procedure CM

A.1. = W_{C1} for AbcD (the continuous members for the time period) = 0

B.1. = W_{C1} for AbDE (the continuous members for the time period)

= (1/4) x 8,000 = 8,000 = 2,000

C.1. = W_{C1} for AbD (the continuous members for the time period) = 0

A.2. = W_{C2} for AbcD (the continuous members for the time period)

(3/4) x 4,000 = 3,000

B.2. = W_{C2} for AbDE (the continuous members for the time period)

= (2/4) x 4,000 + (1/4) x 8,000 = 4,000

C.2. = W_{C2} for AbD (the continuous members for the time period)

= (2/3) x 4,000 = 2,666.67

Procedure AW

A.1. = [[(W_{C1} for AbcD) · 7 months] + [(W_{C1} for AbcDE) · 5 months]]/12 months

= [[(0) · 7] + [(1,600) · 5]]/12 = 666.67

B.1. = [[(W_{C1} for AbcDE) · 3 months] + [(W_{C1} for AbDE) · 9 months]]/12 months

= [[(1,600) · 3] + [(2,000) · 9]]/12 = 1,900

C.1. = [[(W_{C1} for AbcD) · 7 months] + [(W_{C1} for AbcDE) · 8 months] + [(W_{C1} for AbDE) · 9 months]]/24 months

= [[(0) · 7] + [(1,600) · 8] + [(2,000) · 9]]/24 = 1,283.33

A.2. = [[(W_{C2} for AbcD) · 7 months] + [(W_{C2} for AbcDE) · 5 months]]/12 months

= [[(3,000) · 7] + [(4,000) · 5]]/12 = 3,416.67

B.2. = [[(W_{C2} for AbcDE) · 3 months] + [(W_{C2} for AbDE) · 9 months]]/12 months

= [[(4,000) · 3] + [(4,000) · 9]]/12 = 4,000

C.2. = [[(W_{C2} for AbcD) · 7 months] + [(W_{C2} for AbcDE) · 8 months] + [(W_{C2} for AbDE) · 9 months]]/24 months

= [[(3,000) · 7] + [(4,000) · 8] + [(4,000) · 9]]/24 = 3,708.33

Procedure HW

A.1., B.1., C.1. = first wave cross-sectional weight for A = 0 .

A.2., B.2., C.2. = first wave cross-sectional weight for A = 4,000

5. POTENTIAL ADVANTAGES AND DISADVANTAGES

The ideal unbiased weighting procedure would provide a single set of weights applicable to any time interval, require no more data than were collected, and possess the minimum variance among all unbiased procedures. Unfortunately, no such procedure exists. The procedures described in Section 3 all fail one or more of these three criteria to various degrees. In this section, we explain the nature of the failures without explicitly comparing the procedures. That is done in Section 5.

Multiplicity of Weights. Some procedures have the advantage of assigning to each household a single weight which depends only on conditions as of the first reference month for the household and which is valid for every interval

that the household is in the universe. Other procedures have the disadvantage of sometimes producing different weights for the same household for different time intervals. (Procedures with this disadvantage could be modified so that only a single weight applies to any time interval, by computing for each household the weight appropriate for that procedure for the unrestricted universe and the 2 1/2 year time interval corresponding to the life of the panel. The weight obtained would also be used for any smaller subinterval for which the household is in the universe. However, weights obtained in this manner might not be able to be determined until the end of the life of the panel. This would make them difficult to use because we would have to wait until the last data from the panel were processed before estimates could be produced for any earlier time period. In any case, such weights would often lead to higher variances for short time intervals than weights developed specifically for the short time intervals.)

Unavailable Data Requirements. Most definition and procedure combinations require data from some households for time periods when the household is in existence but not in sample, that is for time periods for which interviews are not conducted for the household because no original sample people are members of the household. This needed data could be information for determining proper longitudinal weights or subject-matter information for use in tabulating the estimates. Some of this information is not collected for the 1984 panel of SIPP because of the current operational procedures. This is a consequence of the fact that agreement has not been reached on the longitudinal household definition to be used in SIPP. In this vacuum, operational procedures were determined mainly by considerations of difficulty and cost. Once a definition has been agreed on, depending on the nature of the unavailable data, it might be possible to change operational procedures for future SIPP panels so that

the required data are collected. To understand the problem with current operational procedures, consider the following situation. A household is longitudinal from month t_B to t_E. Original sample people are part of the longitudinal household only from month t_1 to t_2. If $t_B<t_1$, then some prior information may be unavailable. Revised operational procedures to obtain this information might involve retrospective questions, longer reference periods or proxy data on anyone who left the household before the first interview. If $t_2<t_E$, then some posterior information may be unavailable. Revised operational procedures might involve interviewing the household through t_E.

One of the important discriminants between the weighting procedures is how successfully they avoid the need for data from the period that the longitudinal household exists but is not in sample. (The need for such data is avoided by assigning zero weights to these problem households.) In terms of information needed for weighting, some procedures require only enough data to determine whether $t_B<t_1$, while others need to know t_B even when it is less than t_1. Similarly, some procedures only require knowledge of whether $t_2<t_E$, while others need to know t_E even when it is greater than t_2. Furthermore, besides this need for information for determination of weights, if any parameters other than the number of longitudinal households are to be estimated, then required subject-matter data may be missing as well, either before t_1, after t_2, or both.

While the problem of missing information is a serious one, it is not fatal. Procedures can be developed to compensate for the unavailable data. Specifically, the data collected on these households while they were in sample should be sufficient for performing imputation for existence/nonexistence outside the in-sample period and formation and/or dissolution dates. The imputed values can then be used to calculate weights for these households. These households can then be treated as noninterviews so that

the weights of mover households with similar demograpahic characteristics but with complete data receive increased weights while the deficient households themselves receives zero weights.

If the models underlying the procedures developed for adjusting for the missing information are true then it is still possible to obtain unbiased estimators, although now in a model-based sense. Furthermore, since the missing information that we are concerned with here is not caused by refusal to respond, modeling in this context might not suffer from the usually imperfect assumptions on similarity between respondents and nonrespondents that underlie any adjustments that use data from respondents to account for data missing from refusals. In addition, because of the longitudinal nature of the survey, there is generally a large amount of data available from the problem households that could be used in such adjustments. However, if the models are not perfect, then in general, the larger the proportion of data required that is unavailable, the greater the potential for serious bias problems.

Variances. In general, estimation procedures with the smallest variances are those that utilize available data intensively and tailor the weights to the specific time interval of interest. Unfortunately, as shall be seen in the next section, such procedures are often characterized by heavy needs for unavailable data which, as noted above, may impact unfavorably upon bias. Thus, there often is a direct trade-off between variance and the risk of bias. It will be difficult to weigh these factors against each other, since it appears that no single procedure will provide the correct balance for all of the multitude of characteristics that will be estimated by SIPP.

For use in the next section, we will define some labels for the advantages and disadvantages identified in the foregoing discussion. Let:

T_1 mean that a single longitudinal weight exists for each household, valid for all time intervals for which the household is in the universe, and which depends only on conditions which could be determined during the first interview,

T_2 mean the negation of T_1,

BW_1 mean that no data from the period preceeding the first interview are unavailable but required for weighting,

BW_2 mean that we need to know for weighting whether the longitudinal household existed before the first interview,

BW_3 mean that we need to know for weighting the conception date of the household (within the time interval of interest),

BD_1 mean that no subject-matter data from the period preceeding the first interview are unavailable but required,

BD_2 mean the negation of BD_1,

FW_1 mean that no data from the period following the last interview are unavailable but required for weighting,

FW_2 mean that we need to know for weighting the dissolution date of the household (within the time interval of interest),

FD_1 mean that no subject-matter data from the period following the last interview are unavailable but required,

FD_2 mean the negation of FD_1.

Note that T_1, BW_1, BD_1, FW_1 and FD_1 are the desirable properties.

6. DETAILED COMPARISONS OF ADVANTAGES AND DISADVANTAGES

Table 1 below presents advantages and disadvantages of each definition procedure and universe combination. A comparison of these features follows the table. Next, an explanation of each entry in the table is given. Finally, a discussion of data utilization, which is not in Table 1, is presented.

Table 1.

Features

Definition	Procedures	Universe	T_1	T_2	BW_1	BW_2	BW_3	BD_1	BD_2	FW_1	FW_2	FD_1	FD_2
No Change (NC)	All	Both	X		X			X		X		X	
Same Householder (SH)	Householder Weight (HW)	Both	X		X			X		X		X	
Same Householder (SH) Reciprocal Majority (RM) Shared Experiences (SE)	Beginning Date of Household (BH)	Unrestricted	X			X		X		X			X
SH, RM, SE	BH	Restricted	X			X		X			X		X
SH, RM, SE	Beginning Date of Time Interval (BI)	Unrestricted		X		X		X		X			X
SH, RM, SE	BI	Restricted		X	X			X			X		X
SH, RM, SE	Continuous Household Members (CM)	Restricted		X	X			X		X		X	
SH, RM, SE	Average Cross-Sectional Weight (AW)	Both		X			X		X		X		X

Comparison of Features in Table 1. As noted at the end of Section 4, T_1, BW_1, BD_1, FW_1, and FD_1 are the desirable properties. For the NC definition all five procedures considered here possess all these desirable properties, as does the HW procedure for the SH definition.

However, for the SH, RM, and SE definitions, and most other definitions too, the BH, BI, and CM procedures have different subsets of the set of desirable features, so that the procedure to be adopted depends, at least in part on the features deemed most important. AW possesses none of these desirable features for there three definitions. Its principal advantage lies in possible reductions in variances because of complete utilization of available data, which will be discussed later. BH has advantages T_1, BD_1, and FW_1 for the unrestricted universe, and T_1 and BD_1 for the restricted universe. The main reason for consideration of this procedure would be that it is the only one among BH, BI and CM that always has advantage T_1. BI has advantages BD_1 and FW_1 for the unrestricted universe and BW_1 and BD_1 for the restricted universe. Its principal advantage over BH is that for the restricted universe no retrospective questions need be asked. CM (which is only applicable to the restricted universe) possesses all desirable features except T_1, that is no information not currently collected is needed for this procedure. Recall, however, that CM had the disadvantage of being slightly biased as explained in Section 3.

Explanation of Entries in Table 1. All explanations presented below apply to both universes unless otherwise stated.

NC Definition, All Procedures. Since the composition of a household is unchanged throughout its period of existence under NC, we have the following two possibilities:

(a) No original sample people were in the household at any time during its period of existence, in which case the longitudinal household weight is zero for any time interval and procedure.

(b) One or more original sample people were in the household throughout its existence, in which case the beginning and ending dates of the household are known, as is the composition of the household and complete data for each month of its existence. Consequently, features BW_1, BD_1, FW_1, and FD_1 apply.

Furthermore, T_1 applies since procedures BH, BI, CM, and AW all reduce to the cross-sectional household weight at the beginning date of the household, while HW is the weight of the householder at the beginning date.

SH Definition, HW Procedure. The explanation is similar to the one given above, except now the two cases are: (a) The householder was not an original sample person. (b) The householder was an original sample person.

SH, RM, and SE Definitions, BH Procedure. T_1 is applicable, since by definition the weight is the cross-sectional household weight as of the beginning date of the household. BW_2 applies because the longitudinal household weight is the cross-sectional household weight as of the first month in sample if the household began that month, while otherwise the weight will be zero since there were no original sample people in the household when it began. (For the restricted universe, households which entered sample after the beginning of the time interval always receive a zero weight.)

BD_1 holds since all households with positive weights were in sample at their beginning date and no retrospective subject-matter data is therefore needed.

FW_1 holds for the unrestricted universe since the weight is determined at the beginning date of the household. However, for the restricted universe, it is necessary to know if the household continued to exist throughout the entire time interval because it receives a zero weight for the time interval if it did not continue. Under current procedures a household which no longer has any original sample person is not followed, and it would therefore generally

not be possible to determine if it remained in existence for the entire time interval. Consequently, FW_2 applies.

FD_2 applies since there would be missing data for all households with positive weights which continued to exist after there were no longer any original sample people present, which could happen for any of there three definitions.

SH, RM, and SE Definitions, BI Procedure. T_2 is applicable since time intervals with different beginning dates may yield different longitudinal weights. BW_1 applies for the restricted universe, since the longitudinal weight is the cross-sectional household weight as of the first month of the time interval for all households in sample that month, and zero for all other households. However, BW_2 applies for the unrestricted universe since longitudinal households that entered sample after the beginning of the time interval are treated as in the BH procedure.

BD_1 holds since any household with a positive weight was either in sample the first month of the time interval or the month that the household began, and consequently, no retrospective data are needed.

As in the BH procedure, and for the same reasons, FW_1 applies for the unrestricted universe, FW_2 for the restricted universe and FD_2 for both universes.

SH, RM, and SE Definitions, CM Procedure, Restricted Universe. T_2 is applicable since any two intervals may yield different longitudinal weights.

Furthermore, BW_1, BD_1, FW_1, and FD_1 apply. The explanation is similar to that given for the NC definition except now the two cases are:
(a) No original sample people were household members for the entire time interval. (b) At least one original sample person was a household member for the entire time interval.

SH, RM, and SE Definitions, AW Procedure. T_2 is applicable since any two time intervals may yield different longitudinal weights.

Any household that contained an original sample person for at least one month of the time interval receives a positive longitudinal weight for the unrestricted universe, while for the restricted universe it receives a positive weight if it also existed for the entire time interval. However, for either universe such a household might have existed for months when there were no original sample persons in the household, both before and after it came into sample. Hence BD_2 and FD_2 apply. Furthermore, in order to compute the longitudinal household weight it is necessary to determine if the household was in existence at the beginning and the end of the time interval for both universes, and in addition for the unrestricted universe, the beginning and ending dates if they are within the time interval. Hence BW_3 and FW_2 hold.

Utilization of Data. Having compared the procedures with respect to needs for unavailable data and the multiplicity of weights, we now turn our attention to variance. To compare the variance characteristics of the procedures we will focus on the amount of collected data that is used in obtaining estimates, since this is a primary determinant of variance. This discussion will also better illustrate the proportion of data needed for estimation that is unavailable for each procedure. In general, the greater this proportion is, the larger the burden is on any missing data procedure employed, with a resulting greater potential for bias problems. To make the comparison we show in Table 2, all 24 possible cases of how the data on a longitudinal household may be complete, partly available, or nonexistent for a particular time interval.

The symbols t_B, t_1, t_2, and t_E denote beginning date of household, first sample month, last sample month, and ending date of household respectively. The columns indicate different time intervals. Interval B is the interval of interest. Interval A is from t_B until the beginning of interval B, while interval C is from the end of interval B until t_E. The fifth case, for

example, is of a household that formed before interval B about which we are missing some data pertinent to the early part of interval B. The first nine cases comprise the restricted universe. The last 15 cases fill out the unrestricted universe. Each case is marked as having complete data, partial data, or no data. Of course, all of this is assuming perfect response. The only type of missingness that we are discussing here is that caused by operational procedures. On the right there is a column for each procedure with an "A" entered if it always uses the case, an "S" if it sometimes uses the case but not always (which will be explained in the discussion that follows), and a blank otherwise. These comparisons do not apply to the NC definition, for which all five procedures use all the complete cases and no other cases.

Table 2.

Data Utilization

	Interval A	Interval B	Interval C	Completeness	Procedure BH	BI	CM	AW	HW
1	$t_B=t_1$		$t_2<t_E$	perfect	A	A	S	A	S
2	$t_B<t_1$		$t_2<t_E$	perfect		A	S	A	
3	$t_B=t_1$	t_2	t_E	some missing	A	A		A	
4	$t_B<t_1$	t_2	t_E	some missing		A		A	
5	t_B	t_1	$t_2<t_E$	some missing				A	
6	t_B	t_1 t_2	t_E	some missing				A	
7	$t_B=t_1$ t_2		t_E	all missing	A				
8	$t_B<t_1$ t_2		t_E	all missing					
9	t_B		t_1 $t_2<t_E$	all missing					
10	$t_B=t_1$	$t_2=t_E$		perfect	A	A		A	S
11	$t_B<t_1$	$t_2=t_E$		perfect		A		A	
12		$t_B=t_1$	$t_2<t_E$	perfect	A	A		A	S
13		$t_B=t_1$ $t_2=t_E$		perfect	A	A		A	S
14	$t_B=t_1$	$t_2<t_E$		some missing	A	A		A	
15	$t_B<t_1$	$t_2<t_E$		some missing		A		A	
16		$t_B=t_1$ $t_2<t_E$		some missing	A	A		A	
17		$t_B=t_1$ t_2	t_E	some missing	A	A		A	
18	t_B	t_1 $t_2<t_E$		some missing				A	
19		$t_B<t_1$ $t_2<t_E$		some missing				A	
20		$t_B<t_1$ t_2	t_E	some missing				A	
21		$t_B<t_1$	$t_2<t_E$	some missing				A	
22	$t_B=t_1$ t_2	t_E		all missing	A				
23	$t_B<t_1$ t_2	t_E		all missing					
24		t_B	t_1 $t_2<t_E$	all missing					

The BH procedure uses the complete cases 1, 10, 12, and 13, but does not use the complete cases 2 and 11. It also uses the partial cases 3, 14, 16, and 17, and cases 7 and 22 for which there is no data in interval B. The BI procedure uses all the complete cases, more of the partial cases and none of the cases with no data. We thus think the BI procedure will tend to produce smaller variances than the BH procedure since it uses more of the available data. However, it is not clear in general which of these two procedures has the smaller proportion of needed data that is missing.

The CM procedure is appealing for the restricted universe since it uses all the complete cases (except in the rare situation when there is at least one original sample person present for every month of interval B, but none of them are present for the entire interval), and none of the other cases. It should thus have fairly small variances and has only the slight bias indicated in Section 3. However, it is not applicable to the unrestricted universe.

The HW procedure uses the same complete cases as the BH procedure, except it does not use these cases when the householder is not an original sample person, and it uses none of the other cases. However, it is not applicable to the RM, SE, and most other longitudinal household definitions.

The AW procedure is the most aggressive in utilizing partial data. It uses all the complete and partial cases while avoiding the cases with no data. Also note that it assigns smaller weights, in general, to the partial cases than the complete cases. We believe it will tend to produce the smallest variances for most definitions, particularly in the unrestricted universe, but also tends to have the highest proportion of data that is needed for estimation but unavailable.

7. ADJUSTMENTS OF ESTIMATES

In this section we will present some general ideas on adjustments to be made to the unbiased longitudinal household weights that would be obtained using any of the procedures described in Section 3. These should be considered only as preliminary thoughts, as many details remain to be worked out, and even the general approach is subject to change. The proposed procedures are somewhat analogous to the procedures used for cross-sectional estimates, and contain the following four components: an adjustment for the purpose of reducing between PSU sampling variability; an adjustment for household non-interview in second and subsequent waves; and a final adjustment to CPS estimates of the number of households by age-race-sex category of householder.

The first suggested step in the process of adjusting the unbiased weights does not actually begin with these weights, but instead alters the output of Section 3, so the resulting weights contain adjustments for first wave noninterview, and to reduce between PSU sampling variability. To do this, we simply alter the description in Section 3 of the first wave cross-sectional weight to now include these two adjustment factors in addition to the reciprocal of the probability of selection.

Two further adjustments would be performed on the weights resulting from the modification described in the previous paragraph. The need for the first adjustment would arise because there would be longitudinal households resulting from wave one respondent households for which there were missing data, not "completed" by imputation, for at least part of the time interval for which estimates are desired. This adjustment would redistribute the weights of such households to all households in the same weighting cells with complete data, in proportion to the weights of the households with complete data. In performing this adjustment it should be noted that in the case of

households for which complete contact is lost after some point, subsequent household compositional changes may alter the weights of the noninterview households, so it is not always clear what are the correct weights to redistribute. Imputation of these weights would appear to be necessary.

The final proposed adjustment would adjust the SIPP sample estimate of number of longitudinal households whose householder is in a given age-race-sex category to the CPS estimate. This would be accomplished by multiplying each household weight in the given cell by the ratio of the CPS estimate of the number of households in the cell to the SIPP estimate. (Family estimates could be controlled to CPS estimates by further dividing each cell into family and non-family household subcells. Even finer subdivision is also possible.) There are several possible approaches to computing this adjustment factor for each cell. The simplest would be to compute the factors at one month during the time interval in question, where the denominator of the ratio would be the sum of the weights of all longitudinal households in the cell in existence during that month, and then applying that same factor also to all other longitudinal households in the cell. (This was done in NMCUES (Whitmore, Cox, and Folsom 1982).) If this approach is taken then, in general, the SIPP and CPS estimates of the number of households in a given cell, and even the estimated total number of households in the universe, would not agree for any other month.

If it is required that the SIPP longitudinal household estimates in each cell agree with CPS estimates for every month in a time interval, then this could be accomplished by grouping the longitudinal households in each cell according to their pair of beginning and ending dates, and applying a different weighting factor for each such group. The values for these factors could be determined by considering them as variables in a mathematical

programming problem. This is described in detail by Judkins et al. (1984). Caution should be taken before adopting such a technique to control household weights for every month in a time interval. In certain situations no solution would be possible unless some weighting factors were allowed to be very large, or even negative. It may sometimes even occur that there is no solution even when there are no constraints on the weighting factors. Furthermore, slight changes in the objective function or the constraints might dramatically change some weighting factors. Finally, under some of the proposed definitions the householder in a longitudinal household may change, placing the household in a different age-race-sex cell, and requiring a modification of the procedure to account for this problem.

Some necessary imperfections in the CPS household control totals should also be noted. Although the CPS estimates of total individuals in a given age-race-sex category are themselves controlled to independent demographic estimates which have no sampling variability, the number of householders in each category is not controlled in this manner. This is troubling because the process which yields the CPS estimates of households is subject to unknown biases. Despite this, it is felt that this use of CPS estimates in adjusting SIPP data would reduce total sampling variability and many biases because of the combination of the demographic estimate controls and the larger size of the CPS sample.

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