THE SURVEY OF INCOME AND PROGRAM PARTICIPATION

WITHIN-PSU SORT AND STRATIFICATION RESEARCH TO IMPROVE SURVEY EFFICIENCY

No. 155 9115

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U. S. Department of Commerce BUREAU OF THE CENSUS

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I. INTRODUCTION

After each decennial census, the Bureau of the Census redesigns its household surveys to improve their efficiency. One project done to identify potential improvement is within-Primary Sampling Unit (PSU) sort and stratification research. The surveys currently doing this research are

American Housing Survey-Metropolitan Sample (AHS-MS),
Consumer Expenditure Survey (CE),
Current Population Survey (CPS),
Health Interview Survey (HIS),
National Crime Survey (NCS),
Point of Purchase Survey (CPP), and
Survey of Income and Program Participation (SIPP).

This paper describes the research for an optimal sort and stratification scheme to reduce the within-PSU variance of key survey estimates. The research involves three parts:

Selection of Sort and Stratification Variables,
Obtaining Sort and Stratification Schemes,
Evaluation of Stability of Sort Variables Over Time.

The first part is similar to research done prior to the last redesign. See [1]. The second considers new approaches to forming sort and stratification schemes. The third is new for this redesign.

After providing background information, this paper discusses the three research parts with emphasis on the second part. Also, this paper presents an application of the research to the SIPP and concludes with suggestions for further research.

II. BACKGROUND

For redesign, the universe (households in the United States) is sorted or stratified either at the housing unit level or at the census block level. So, ideally, research should be done at both levels. Due to time and resource constraints, the first two parts of the research use only block level data. The block level research is, however, conducted on areas where the universe is sorted or stratified by blocks and by units. The intent of each redesigning survey is to apply the block level scheme to the unit and block levels. (The CPS uses only block level sorts.) If an ordering of a set of variables at the block level reduces the within-PSU variance for key survey estimates, that ordering and set of variables at the unit level is expected to reduce those variances more. So, a scheme performing well at the block level is expected to perform even better at the unit level.

Stability research requires longitudinal data. Since the only available longitudinal data, AHS-MS, for the research is at the unit level, the stability research uses unit level data.

The following sections discuss each part of the research.

III. SELECTION OF SORT AND STRATIFICATION VARIABLES

We identified potential sort or stratification variables based on sponsor requirements, past research, or knowledge of the relationships between variables. Some of us based our selection entirely on these three items, while others did further research. The further research involved three parts:

1. correlations between variables and key survey estimates
2. scatterplots for the variables and key survey estimates
3. stepwise regression of key survey estimates with the variables

We added variables to the list of potential sort and stratification variables based on the results from this analysis.

Since we conducted research using blocks, the sort and stratification variables were proportions or medians of a characteristic found within the blocks. If we did research at the unit level, we would use the actual value of a sort and stratification variable for each housing unit. The sort and stratification variables described demographic, geographic, and socio-economic characteristics of a block. We used only census data asked of all households (100% census data) for the sort and stratification variables. Since some of the blocks in a PSU did not have census data asked only to a sample of households (sample census data), we did not use sample census data for stratification.

Key survey estimates were totals found within the blocks. We used both 100% census data and sample census data for the key survey estimates.

For the sort and stratification variables and key survey estimates, we used 100% data and sample data from the 1980 census block level files for eleven urban and five rural PSUs. See [2]. We selected these PSUs for research because they were blocked in 1980. All PSUs in the country were not blocked in 1980. Also, we believed that this group represented the country. Below are the PSUs used for the research.

Counties in Urban PSUs

1. Contra Costa, CA	6. Oakland, Wayne, MI
2. Suffolk, NY	7. Essex, Hudson, Union, NJ
3. DeKalb, Forsyth, Fulton, GA	8. Albany, Rensselaer, NY
4. Cook, Dupage, Lake, IL	9. Arlington, Fairfax, Prince William, VA
5. Suffolk, MA	10. Dallas, TX
	11. Stanislaus, CA

Counties in Rural PSUs

1. Camden, Charlton, GA	4. Genesee, Wyoming, NY
2. Attala, Holmes, MS	5. Appomattox, Charlotte, Prince Edward, VA
3. Deer Lodge, Silver Bow, MT	

IV. METHODOLOGY TO OBTAIN SORT AND STRATIFICATION SCHEMES

A. <u>Creation of Sort and Stratification Schemes</u>

To create the sort and stratification schemes, we used one of the following three procedures.

1. Forming strata, sorting strata, sorting blocks within strata
2. Forming strata, sorting blocks within strata
3. Sorting blocks within the PSU

In the first and second procedures, we formed strata by dividing a variable or cross-clarification of variables into categories. Then we placed a block with a certain percentage or median of that variable in the appropriate category or stratum.

We sorted the strata in either ascending or descending order for the first procedure using the value of a weighted average of another variable.

In all three procedures, the last step is the sorting of the blocks. We sorted blocks in either ascending or descending order. Depending upon the procedure, we sorted blocks by their value of a variable within the stratum or across the entire PSU.

We used three methods to assign blocks to strata. For each method, we determined the boundaries of the strata by the proportional value or the median value of the stratification variable.

For the first method, we set the boundaries to be the same for all the PSUs. For example, the four strata for the variable proportion of minorities 0+ of the total population 0+ for all the PSUs can be [0, .25), [.25, .50), [.50, .75), and [.75, 1].

The advantage to the first method is that no prior knowledge of the distribution is needed. Also, from a programming aspect, this method is the least costly to implement compared to the next two methods of forming strata. The drawback for this method is that a stratum may be empty for any PSU. Also, the distribution of units in each stratum may be different. So, the stratification may not be as effective in reducing variances.

The second method is to set boundaries so that each stratum has the same percentage of blocks for all PSUs. For example, the four strata for the variable proportion of minorities 0+ of the total population 0+ for all the PSUs can have 25% of the distribution in each of the 4 stratum. Ideally, each stratum contains the same percentage of the distribution. However, in practice, this may not be possible to achieve. See [3].

The advantage to the second method is that a greater variance reduction is obtained compared to the first method. For this method, the values of the boundaries will be different for all PSUs. Also, the distribution of a variable for the PSU must be known to determine boundaries which place a certain percentage of blocks in a stratum. The drawback for this method is the need for more programming and computer costs.

The third method to set boundaries is a combination of the first and second methods. The first and last strata have the same values for all PSUs, while the middle strata have a fixed percentage of the leftover distribution. Depending upon the leftover distribution, the middle strata may have approximately equal percentages. For example, the four strata for the variable proportion of minorities 0+ of the total population 0+ for all PSUs can be [0, .10) for the first stratum, (.90, 1] for the fourth stratum, the first 50% of the remaining distribution in the second stratum, and the second 50% of the remaining distribution in the third stratum. For many of the variables, the first and fourth strata are not empty because there is a clustering at the tails of the distribution.

The advantage to the third method is that a greater variance reduction is obtained compared to the first method. For this method, the values of the boundaries for the middle strata will be different for all PSUs. Also, the percentage of the total distribution of a variable for a PSU must be known. The drawback for this method is that it requires more programming and computer needs than the other two methods.

B. <u>Selection of Sort and Stratification Schemes</u>

To determine the sort and stratification schemes that are most effective in reducing the within-PSU variance of key survey estimates, we calculated the between-block variance of key survey estimates for each PSU under each scheme. See [4] and [5]. For each PSU, we calculated the between-block variance over all possible systematic samples of each scheme assuming a fixed sample size. For the systematic samples, we computed the estimated total ($\hat{Y}$) as:

$$\hat{Y} = \frac{1}{SI} \sum_{k=1}^{SI} \hat{Y}_k$$

and the between-block variance of the estimated total ($\hat{Y}$) as:

$$Var\ (\hat{Y}) = \frac{1}{SI} \sum_{k=1}^{SI} (\hat{Y}_k - \hat{Y})^2$$

and, for a given sample k, the estimate ($\hat{Y}_k$) as:

$$\hat{Y}_k = SI \sum_{i=1}^{T} \left(m_{ik}\ \frac{x_i}{M_i}\right)$$

where

x_i = count or total of the characteristics of interest (persons, households, or housing units) for the i^{th} block in the given PSU,

M_i = the total number of housing units in the i^{th} block,

m_{ik} = the number of sample housing units in the i^{th} block for the k^{th} systematic sample (m_{ik} = 0, when the i^{th} block is not in the k^{th} systematic sample),

T = the total number of blocks in the given PSU,

SI = the sampling interval for the given PSU and all possible systematic samples.

As benchmarks for each PSU, we calculated between-block variances for key survey estimates by a random sort and a geographic sort of the blocks. For the random sort, we assigned each block with a random number and then sorted by that random number. We defined the geographic sort as the county code, tract number, and block number. We compared the variances from the sort and stratification schemes to these benchmarks to determine if the sort schemes reduce the variances. We, also, compared ratios of the variances from different sort and stratification schemes to see which scheme provided a better variance reduction.

VI. EVALUATION OF STABILITY OF SORT VARIABLES OVER TIME

During the actual sample selection process, 1990 census data is used to sort and stratify units and blocks in the United States. Then, sample is selected for 1995 through 2005. Actual characteristics of selected units and blocks may change by the time of the interview. So, sort and stratification schemes which reduced variances of key survey estimates in 1990 may produce smaller variance reductions with time or may result in increased variances compared to the random or geographic ordering of units or blocks. Even if variance reductions are possible during the ten year period, different orderings of the sort and stratification variables may result in smaller variances over time.

We evaluated the stability of the sort and stratification variables with longitudinal data from 7 metropolitan statistical areas (MSAs) of the AHS-MS. The longitudinal data included data from the same housing units for the years 1974, 1977, 1981, and 1985. The actual types of characteristics available are limited and did not cover all the sort and stratification variables considered. Below are the MSAs used for this research.

1. Boston
2. Dallas
3. Detroit
4. Fort Worth
5. Minneapolis/Saint Paul
6. Phoenix
7. Washington, D.C.

From the AHS-MS data, we analyzed two sets of correlations. The first set involved correlations between sort and stratification variables in 1974 and in the other three years, 1977, 1981, and 1985. The second set involved correlations between sort and stratification variables in 1974 and key survey estimates at each of the four years.

We considered the following criteria for stability. When both sets of correlations for a sort and stratification variable were high and stable over time, then we judged that sort and stratification variable to be suitable. When the correlations deteriorated over time and became negative, then we considered that sort and stratification variable inappropriate. When the correlations over time were more stable for one sort and stratification variable than for another with a similar initial correlation, then we selected the more stable variable to be higher in the sort and stratification scheme.

VII. RESULTS FROM THE SIPP

One survey involved in the within-PSU sort and stratification research is the Survey of Income and Program Participation (SIPP). The following illustrates the research done for the SIPP.

A. Estimates and Variables Used for SIPP Research

For the research, we in the SIPP branch analyzed 14 key survey estimates. (See Figure 1.) Five were poverty-related estimates. The first, second, and third poverty-related estimates used sample census data; the fourth and fifth used 100% census data. Four were labor force and income estimates. All used sample census data. The 5 other key SIPP estimates used 100% census data.

We initially considered the following 12 sort and stratification variables.

1. proportion of minority population 0+ of the total population 0+
2. proportion of persons 65+ of the total population 0+
3. proportion of persons 0+ in urban areas of the total population 0+
4. proportion of vacant year-round HUs of total year-round HUs
5. proportion of one-room year-round HUs of total year-round HUs
6. proportion of renter-occupied HUs of total occupied HUs
7. proportion of minority renter-occupied HUs of total occupied HUs
8. proportion of renter-occupied HUs with contract rent less than $150 of total occupied HUs
9. proportion of mobile homes or trailers of total year-round HUs
10. median value of owner-occupied HUs
11. median contract rent
12. CBUR

CBUR classifies the location of an area. The C represents the central city of an MSA. The B represents an urbanized area not in category C. The U represents an urban place not an urbanized area and not in category C. The R represents all other areas. See [6]. Due to problems during the research with the block level files, the classification for the geographic variable was CUR. For research, blocks with the B classification did not exist on the file. For implementation, the classification is CBUR.

B. Selection of Sort and Stratification Variables

From the list of 12 variables, we selected seven (1, 2, 6, 7, 8, 11, and 12) for the research based on the results of the correlations, scatterplots, and regression analysis from all the PSUs.

Two variables showed a correlation greater than .25 between the black-related survey estimates in all the PSUs. They were proportion of minority population 0+ of total population 0+ and proportion of minority renter-occupied HUs of total occupied HUs. In the PSUs with a high percentage of blacks in the population, the correlation was greater than .60 between these two variables and the black-related survey estimates.

C. Selection of Sort and Stratification Scheme

For the research of a scheme, we selected all odd-numbered urban and rural PSUs from section 3, except urban PSU 9. We saved all even-numbered urban and rural PSUs to test the effectiveness of the sort and stratification scheme. Due to time constraints, we only tested the final scheme on PSU 2.

As we produced the benchmarks for the within-PSU variances in urban PSUs, the geographic sort proved better in reducing the variances than the random sort for every key survey estimate except for three estimates in PSU 2 (the test PSU), three estimates in PSU 7, and one estimate in PSU 11. However, for rural PSUs, the geographic sort proved better in reducing the variances than the random sort for only 57 percent of the survey estimates. One cause for this may be the number of blocks in the PSUs. The rural PSUs have fewer blocks than the urban PSUs.

To obtain a unique ordering of blocks in the sort, we ended every scheme with three geographic identification variables: county code, tract number, and block number. These three geographic identification variables defined the geographic sort.

Initially, we sorted blocks within the PSU. After different sort combinations in both urban and rural PSUs, we did not find a significant reduction in the variances of the survey estimates. The only sort scheme that showed any measurable reduction was CBUR followed by the three geographic variables.

In forming strata, we began with the two variables that showed a high correlation between the black-related survey estimates. We set the values of the boundaries to the strata for these variables to be the same in each PSU. Some PSUs, especially urban PSUs, showed modest reductions in the variances while variances in other PSUs, especially rural PSUs, only worsened. We selected two stratification levels. They were proportion of minority population 0+ of total population 0+ and proportion of minority renter-occupied HUs of total occupied HUs for the first and second level, respectively. This ordering of levels showed a greater reduction in the variances than any other ordering with one or both variables. Also, for every stratification scheme, we used two sort orders for the blocks. One sort order was CUR and the three geographic identification variables. The other sort order was just the three geographic identification variables. The first sort order was consistently better than the second sort order for every stratification scheme.

For further trials, we used proportion of minority population 0+ of total population 0+ and proportion of minority renter-occupied HUs of total occupied HUs as the first and second stratification levels, respectively. These additional trials identified two more stratification levels. The third stratification level was median contract rent. The fourth stratification level was proportion of renter-occupied HUs with contract rent less than $150 of total occupied HUs.

With the addition of the third and fourth stratification levels, we reduced the survey estimates related to rent. For some PSUs, especially PSU 3, variance reductions were clear. Unfortunately for some PSUs, especially the rural PSUs, no variance reductions were clear.

Upon investigating the distributions of the four variables used in the stratification, some strata contained only a few blocks. In some instances, strata were even empty. Then we decided to set boundaries by establishing the same percentage of blocks from a variable in each stratum for all PSUs.

Due to time constraints, we only tried to set the boundaries by a percentage of the distribution for the first and second stratification levels. For the variable of the first stratification level, we found two effective stratifications in reducing the variances. For some PSUs, five strata of approximately 20% of the distribution in each stratum was effective. For other PSUs, six strata of approximately 16% of the distribution in each stratum was effective.

To compromise between the two stratifications for the variable of the first level, we set the values of the first and last strata and evenly divided the rest of the distribution into the remaining strata. So, the percentage of the remaining distribution in the middle strata fluctuated for each PSU. Also, the values of the boundaries for the middle strata differed for each PSU. We used six strata for the first stratification level. The values of the first and sixth strata were [0, .01) and (.99, 1], respectively. The four middle strata each contained 25% of the remaining distribution. This stratification proved to be effective in reducing the variances compared to the benchmarks for the urban PSUs. This stratification was not as effective for the rural PSUs.

For the variable of the second stratification level, we found one effective stratification in reducing the variances. The first stratum contained the first 60% of the distribution. This occurred due to the clustering around zero. Many blocks did not have minority renters. The second stratum contained the next 30% of the distribution and the third contained the last 10% of the distribution. For many PSUs, the range for the third stratum started with blocks containing 50% minority renters. For the test PSU, we adjusted the second stratification level because 85.6% of the blocks did not contain any minority renters. We decided to keep the third stratum with 10% of the distribution while adjusting for the difference in the second stratum.

D. Final Research Sort and Stratification Scheme

For the research, the final SIPP sort and stratification scheme for all PSUs included four stratification levels and four sort variables. The variable for the first stratification level, proportion of minority population 0+ of total population 0+, had six strata. The following was the classification of each stratum for the first level.

Stratum	Classification
1st	[0, .01)
2nd	first 25% of the remaining distribution
3rd	second 25% of the remaining distribution
4th	third 25% of the remaining distribution
5th	last 25% of the remaining distribution
6th	(.99, 1]

The variable for the second stratification level, proportion of minority renter-occupied HUs of total occupied HUs had three strata. The following was the classification of each stratum for the second level.

Stratum	Classification
1st	first 60% of the distribution
2nd	next 30% of the distribution
3rd	last 10% of the distribution

The variable for the third stratification level, median contract rent, included five strata. The following was the classification of each stratum for the third level.

Stratum	Classification
1st	no renters in the block
2nd	[$ 0, $ 50]
3rd	($ 50, $110]
4th	($110, $150]
5th	($150, +∞)

The variable for the fourth stratification level, proportion of renter-occupied HUs with contract rent less than $150 of total occupied HUs included four strata. The following was the classification of each stratum for the fourth level.

Stratum	Classification
1st	0
2nd	(0, .5]
3rd	[.5, 1)
4th	1

The sort order for the blocks within the strata included CUR, county code, tract number, and block number.

We tested the above-mentioned scheme only on PSU 2. The scheme proved effective in reducing the variances of the survey estimates for PSU 2. From the research, the above-mentioned scheme for all the urban PSUs showed a reduction in variances compared to the benchmarks for the survey estimates. However, the scheme was not as effective compared to the benchmarks of the rural PSUs. This may be due to the fewer blocks in the rural PSUs. (See Figure 2.)

E. Implementation of the Sort and Stratification Scheme

For implementation, we adjusted the sort and stratification scheme for application to the part of the universe selected at the unit level, to accommodate computer and timing constraints, and to allow for oversampling low income households. There are nine levels of sorting for blocks. There are eight levels of sorting for housing units.

Since we oversample low income households, the first level of sorting classifies units or blocks as follows.

Unit or Block Stratum	Classification
1st	Low Income Households
2nd	Other than Low Income Households

The second level variable classifies units by minority status and blocks by proportion of minority population 0+ of total population 0+. The following is the classification of each stratum for the second level.

Unit Stratum	Unit Classification	Block Stratum	Block Classification
1st	Minority	1st	[.55, 1]
2nd	Not Minority	2nd	[.40, .55)
		3rd	[.15, .40)
		4th	[.05, .15)
		5th	[0, .05)

The third level variable classifies units by renter status and blocks by proportion of minority renter-occupied HUs of total renter-occupied HUs. The following is the classification of each stratum for the third level.

Unit Stratum	Unit Classification	Block Stratum	Block Classification
1st	Renter	1st	[.5, 1]
2nd	Owner	2nd	(0, .5)
		3rd	0
		4th	No renters

The fourth level variable classifies units by contract rent and blocks by median contract rent. The following is the classification of each stratum for the fourth level.

Unit Stratum	Unit Classification	Block Stratum	Block Classification
1st	[$ 0, $ 80)	1st	[$ 0, $100)
2nd	[$ 80, $175)	2nd	[$100, $150)
3rd	[$175, $250)	3rd	[$150, $250)
4th	[$250, +∞)	4th	[$250, +∞)
5th	Does Not Rent		

The fifth level variable classifies units by value of owner-occupied unit and blocks by proportion of contract rent less than $250 of total renter-occupied HUs. The following is the classification of each stratum for the fifth level.

Unit Stratum	Unit Classification	Block Stratum	Block Classification
1st	[$0, $49,999]	1st	1
2nd	[$50,000, +∞)	2nd	[.5, 1)
3rd	Does Not Own	3rd	(0, .5)
		4th	0
		5th	No Renters

The sixth level variable, CBUR, included four strata. The following is the classification of each stratum for units and blocks.

Unit or Block Stratum	Classification
1st	C -- Central City of an MSA
2nd	B -- Urbanized Area not in C
3rd	U -- Urban Place not in B and C
4th	R -- All other areas

The remaining levels uniquely define a housing unit or a block. For the housing units, the seventh and eighth levels are district office and housing unit identification number, respectively. For the blocks, the seventh, eighth, and ninth levels are district office, address register area, and combined block number, respectively.

F. Stability Research

During the research for the sort and stratification scheme, we produced pairwise correlations for the stability research using the AHS-MS unit level data from all seven MSAs. We analyzed the correlations from 1974 versus 1977, 1981, and 1985 for renter-occupied, minority renter-occupied, minority householder, and rent value. Each of these variables remained relatively high across time with minority renter-occupied having the lowest correlated value. All four were similar in stability. (See Figure 3.) We, also, produced correlations of these four variables with key survey estimates. From the analysis of the four variables with the key survey estimates, all the positive correlations remained stable over time. So, we judged the four variables to be suitable as sort and stratification variables for the SIPP.

G. Additional Research For The SIPP

The current sort and stratification research for the SIPP did not investigate the effects of first stratifying by the oversampling variable. Since oversampling will influence additional gains from the sorting, future sort and stratification research for the SIPP should take oversampling into account.

VIII. CONCLUSION

The options presented in this paper may serve as a starting point for sort and stratification research for 2000 redesign. With early planning, we may be able to implement unique sort and stratification schemes in each PSU to obtain further variance reductions. Additionally, the research for the SIPP will include oversampling when developing sort and stratification schemes.

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X. ACKNOWLEDGEMENTS

The research described in this paper has benefitted greatly from the contributions of many people. While we cannot list here all who deserve recognition, we do gratefully acknowledge: Sandra Carnegie and Kathy Kreilick for clerical support; and Michael Ikeda, Susan Hicks, Jim Roebuck, Thomas Moore, Rajendra Singh, and Gary Shapiro for helpful comments.

* This paper reports the general results of research undertaken by Census Bureau staff. The views expressed are attributable to the authors and do not necessarily reflect those of the Census Bureau.

Figure 1. KEY SURVEY ESTIMATES FOR SIPP

Variable	Description of Survey Estimate
	POVERTY-RELATED ESTIMATES
1.	Total Population 0+ Below the Poverty Level
2.	Total Population 0+ Below the Poverty Level Not Receiving Public Assistance
3.	Total Blacks and Hispanics Unemployed 16+
4.	Total Female Headed Households with No Spouse and At Least One Child Under 18
5.	Total Renter-Occupied Housing Units (HUs) with Contract Rent Less than $150
	LABOR FORCE AND INCOME ESTIMATES
6.	Total Blacks 16+ in the Civilian Labor Force (CLF)
7.	Total Population 16+ in the CLF
8.	Total Black Households with Income Between $15,000 and $50,000
9.	Total Households with Income Between $15,000 and $50,000
	OTHER SURVEY ESTIMATES
10.	Total Black Householders
11.	Total Black Population 18+
12.	Total Female Headed Households
13.	Total Population 65+
14.	Total Renter-Occupied HUs

Figure 2.

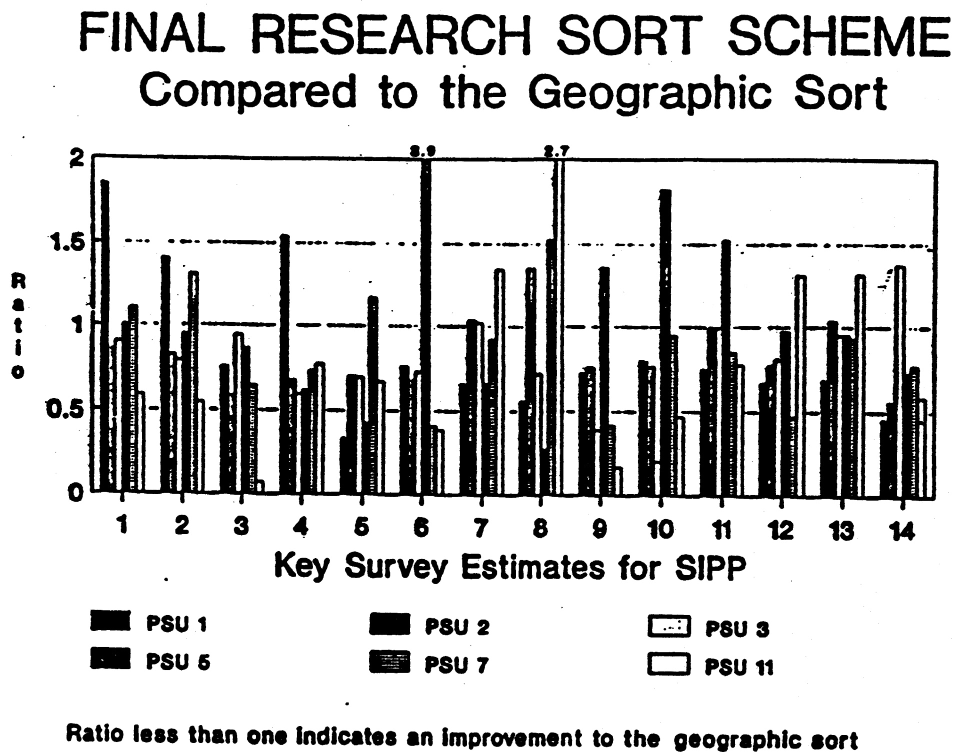

Figure 3. SIPP Stability Correlations

Variable	Years	Minimum	Average	Maximum
Renter Occupied	1974-1977	.82	.87	.91
	1974-1981	.71	.77	.84
	1974-1985	.60	.69	.77
Rent Value	1974-1977	.68	.78	.82
	1974-1981	.50	.66	.74
	1974-1985	.46	.60	.73
Minority Householder	1974-1977	.52	.75	.88
	1974-1981	.44	.66	.81
	1974-1985	.34	.58	.75
Minority Renter Occupied	1974-1977	.35	.63	.82
	1974-1981	.25	.52	.74
	1974-1985	.22	.46	.67