The Expanding Role of Demographic Analysis in 2000 and Beyond

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I. Introduction

The Census Bureau has a long history of evaluating population coverage in decennial censuses. Formal evaluations began with the 1950 census. Almost everything we know about the size of the undercount, trends in census coverage and differences among subgroups of the population come from the Census Bureau's own evaluation programs.

The Census Bureau has used two principal methods to measure the undercount in censuses. One method derives coverage estimates from post-enumeration surveys using dual system estimation. This approach involves case-by-case matching of persons in an independent survey with persons in the census to determine who was missed or counted in error. The survey-based coverage measurement program associated with the 1980 Census was called the Post-Enumeration Program (PEP); in the 1990 Census it was called the Post-Enumeration Survey (PES); for Census 2000 it is known as the Accuracy and Coverage Evaluation (A.C.E). All three programs use a sample survey and the dual system estimation methodology to estimate coverage error.

The Census Bureau has another coverage measurement and evaluation program–Demographic Analysis. Demographic Analysis (DA) represents a macro-level approach, where analytic estimates of population are developed for the census date by aggregating various types of demographic data. Examples are administrative statistics on births, deaths, immigration, and Medicare data, as well as estimates of emigration and undocumented immigration. The difference between the DA estimates and the census count provides an estimate of the net census undercount.

In the Census 2000 evaluation, both coverage programs encountered measurement problems that brought to attention the particular strengths and weaknesses of each program. Thus, an integrated system–that draws from the unique strengths of each program and other data sources–needs to be developed to improve the reliability of the overall estimates of coverage.

In this paper, we discuss the strengths and limitations of Demographic Analysis and discuss how an expanded DA program could be integrated in the coverage measurement for the 2010 census. The DA program evaluates census coverage in "real time" at several points during the census process and extends the scope of the analysis to the State and county group level. We present specific examples to illustrate the strengths of demographic techniques and show how they can inform and improve the census and coverage measurement results in the future.

II. The Method of Demographic Analysis

Demographic Analysis has been extensively used at the Census Bureau to measure coverage of the nation in every census since 1960 (see Siegel and Zelnik, 1966; U.S. Bureau of the Census, 1974, 1988; and Robinson et al, 1993a for the basic demographic evaluations of the 1960 - 1990 censuses).

The traditional method of DA relies heavily on aggregate administrative records, which are independent of the census. For April 1, 2000, the benchmarks for the population below age 65 were derived by the basic demographic accounting equation:

Population (<65) =
- Births (since 1935)
- Deaths (to persons born after 1935)
+ Immigrants (born after 1935)
- Emigrants (born after 1935)

Aggregate Medicare data were used to set the population benchmark aged 65 and over (born before 1935):

Population (65+) =
- Medicare count (of persons aged 65 and older)
+ Estimated un-enrolled (of persons aged 65 and older)

A number of assumptions are made about the completeness of the administrative data used to develop the demographic benchmarks. Since there are no records for some population groups (e.g., unauthorized immigrants, emigrants), the size of some groups must be estimated (see Robinson et al, 1993b, and U.S. Bureau of the Census, 2001a) for a fuller discussion of the demographic components).

Over time the national DA benchmarks have become the standard for measuring national coverage trends and differences by age, sex, and race (Blacks, Nonblacks). The benchmarks have allowed us to document and follow the trend over the last 60 years. The DA net undercount estimate for the total population in Census 2000 (0.1 percent, or 0.3 million) was well below the estimated 5.4 percent in 1940; the undercount has declined for both Blacks and Nonblacks. Despite the universal rate decline, the higher undercount rate for Blacks than for Nonblacks has persisted during the entire period. This persistent differential in the rates is vividly illustrated in Figure 1.

Figure 1 Percent Net Undercount based on Demographic Analysis: 1940 to 2000

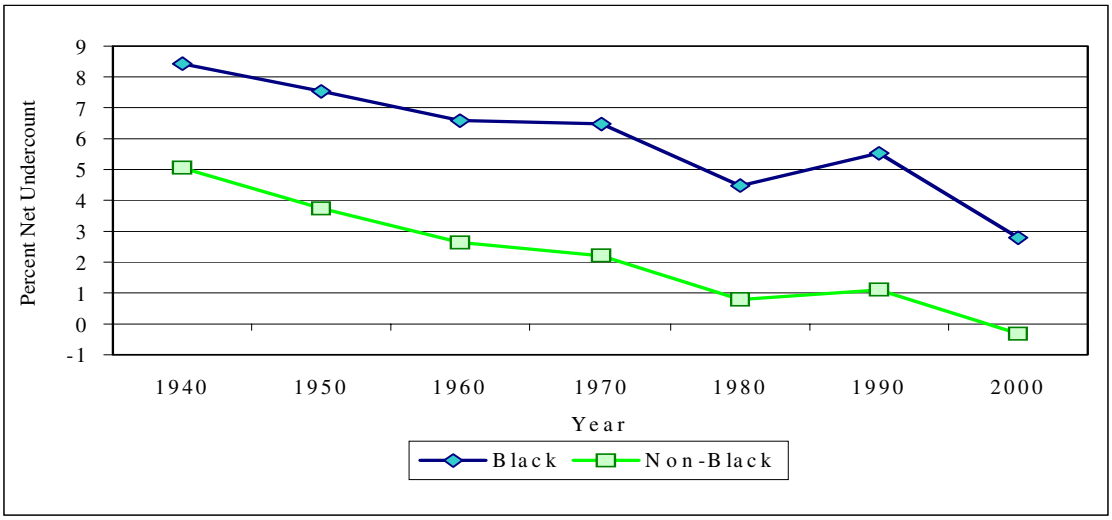
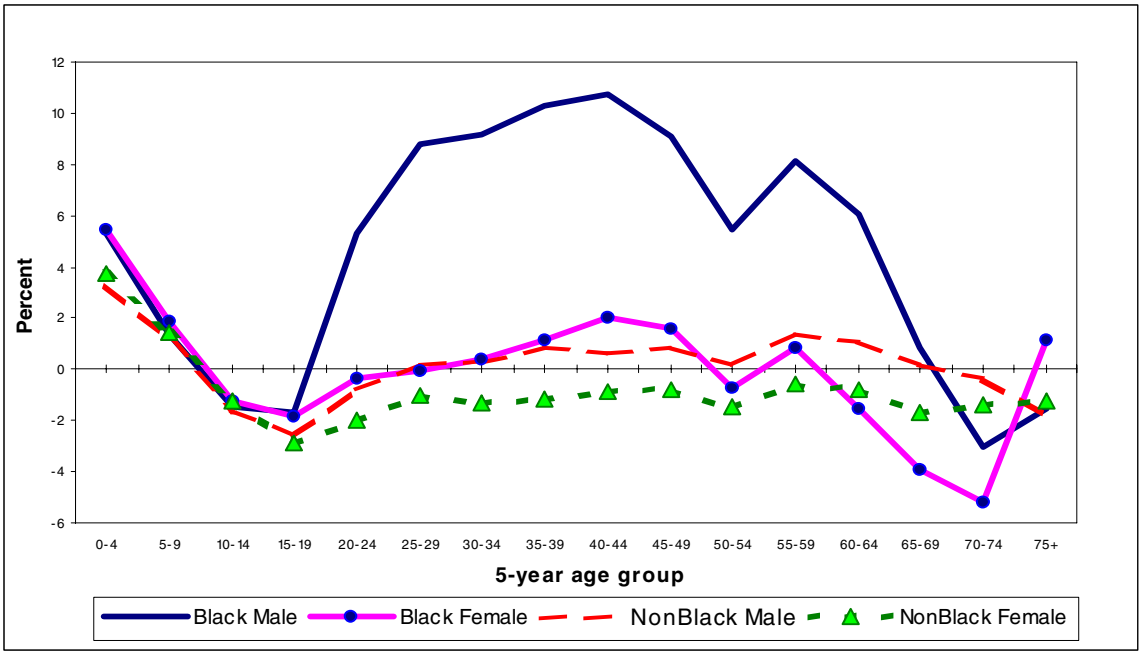


Figure 2 Percent Net Census Undercount by Race, Sex and Age: Revised 2000 DA



The differential undercount has been most pronounced for adult Black men and children regardless of sex (Hogan and Robinson, 1993). The most notable pattern has been the high level of undercount of Black men between ages 20 to 64, where the estimated national undercount exceeds 10 percent in every census from 1940 to 1990. Figure 2 illustrates the disproportionate net undercount among children (ages 0-4) and adult Black males (ages 20 - 64)--compared to the net undercount for other age-sex-race groups in 2000. Age-sex-race patterns of undercount rate are similar in previous censuses, with the overall net undercount levels and differentials between groups dropping in 2000.

III. Comparison Between Demographic Analysis and Coverage Measurement Survey Results: Major Differences in 2000

DA, in addition to its traditional census evaluation role, serves as an important independent benchmark to evaluate the quality of the survey-based estimates of coverage at the national level (e.g., PES in 1990, A.C.E. in 2000). In 1990, the DA and survey results were generally consistent, with the DA estimated undercount of 1.85 percent nearly

matching the PES estimate of 1.58 percent (Table 1). Certain differences were identified in detailed comparisons of the DA and PES estimates for age, sex, and race categories, such as the understatement of the undercount of Black men in the survey relative to DA attributable to "correlation bias," but these discrepancies were similar to DA-survey comparisons of previous censuses. In the evaluation of Census 2000, however, the initial DA undercount estimates were substantially different from the initial A.C.E. results, and each approach implied very different patterns of change in census coverage from 1990. These disparities in the results of the two coverage measurement methods set off an intensive research effort to evaluate each method and ended with revisions that brought the revised estimates closer together (for more discussion of the alternative sets of DA estimates, see U.S. Bureau of the Census, 2001a and 2001b; for discussion of the alternative A.C.E. estimates see U.S. Bureau of the Census, 2003).

Table 1 displays the initial and revised estimates from DA and the A.C.E. for 2000. The initial DA estimate (Base DA) was surprising for two reasons–it implied a relatively large net overcount in the Census (1.8 million, or 0.65 percent), which told a very different story than the A.C.E. which suggested an undercount of 3.3 million (1.15 percent). The DA implied a dramatic change in coverage from 1990; the A.C.E. implied only modest reduction in net undercount. The 5 million difference in the estimated resident population (DA = 279.6 million, A.C.E. = 284.7 million) required explanation.

When we examined the detailed DA estimates by age and sex, we realized that underestimation of immigration in the 1990's, particularly unauthorized migration, could be a reason for these unexpected results. We conducted a systematic analysis of foreign-born data that lead to an alternative assumption about the growth of the immigrant population, in particular, about the increase in the number of unauthorized immigrants. A set of revised DA estimates was prepared in March 2001 to account for the probable understatement of immigration ("Alternative" DA estimates). The Alternative DA estimate of 282.3 million was 0.9 million above the Census 2000 count, implying a small net census undercount of 0.32 percent. The Alternative DA estimate was still well below the March 2001 A.C.E. estimate of 284.7 million, and implied a much greater reduction in net undercount from 1990 compared with the A.C.E. estimate.

Then, between March and October of 2001, we conducted an extensive review of the components of population change used to construct the DA estimates. The research activities were concentrated in two areas: (1) analysis of the administrative records used in the DA estimates (births, deaths, legal international migration, Medicare data), and (2) recalibration of the DA international migration components (in particular, those components that are least well measured- unauthorized migration, emigration, and temporary migration). This review led to revisions of the components used to construct the DA estimates.

The various analyses led to changes in the estimated components of births, deaths, and international migration, but the revised total DA population and the demographic composition of the revised DA estimates were not substantially different from the Alternative DA estimates of March. Compared to the Census 2000 count of 281.4 million, the Revised DA estimate of 281.8 million implied a net census undercount of 0.12 percent. The net census undercount in 2000 remained dramatically different from that in the 1990 under the revised DA set. In 1990, the revised net undercount was 4.2 million, or 1.65 percent.

The parallel examination of the A.C.E. methodology and estimates found that the initial A.C.E. results overstated the resident population, in large part due to millions of duplicates in Census 2000 that were not detected in the initial estimates (U.S. Bureau of the Census, 2003). Along with other changes, the A.C.E. estimate was lowered from 284.7 million to 278.4 million, yielding an estimated net overcount of 1.09 percent. In a final revision, the A.C.E.estimates (called A.C.E. Revision II) for males were adjusted for correlation bias by using sex ratios from DA. This step raised the A.C.E. Revision II estimate to 280.1 million (or net overcount of 0.48 percent). The A.C.E. Revision II estimate was now lower than the DA estimate (281.8 million, or net undercount of 0.12 percent), the reverse of the initial DA and A.C.E. comparison.

It is important to note that the A.C.E. provides more detailed understanding of the scope of the differential undercount, yielding direct estimates for seven race/Hispanic origin groups, broad geographic areas, and households classified by tenure. The two very different estimation methods (DA and coverage measurement surveys) complement each other. DA illustrates the long-standing nature of the disproportionate undercounts and the A.C.E. shows how these differentials are related to social and geographic groups.

Table 1. Percent Net Undercount based on Demographic Analysis (DA) and Coverage Measurement Survey Methods (PES, A.C.E.): 1990 and 2000 (Numbers in Millions)

Census, Method, and Set	Count or Estimate	Net Undercount	
		Number	Percent
1990			
Census	248.7	x	x
DA			
Original	253.4	4.7	1.85
Revised	252.9	4.2	1.65
PES	252.7	4.0	1.58
2000			
Census	281.4	x	x
DA			
Base (January 2001)	279.6	-1.8	-0.65
Alternative (March 2001)	282.3	0.9	0.32
Revised (October 2001)	281.8	0.3	0.12
A.C.E.			
March 2001	284.7	3.3	1.15
December 2002 (A.C.E. Revision II)			
No adjustment for Correlation Bias	278.4	-3.0	-1.09
With adjustment for Correlation Bias	280.1	-1.3	-0.48

IV. Expanded Scope of Demographic Analysis Program

Traditionally, the DA program has been used to evaluate the consistency of census results and completeness of coverage at the national level, as well as to assess the estimates of undercount derived from post-enumeration surveys. The Demographic Analysis program was expanded recently to produce coverage benchmarks on a more timely basis and below the national level. In addition, the new analytic program includes the use of housing estimates developed as part of the Census Bureau's estimate program as independent benchmark checks. Early in the Census 2000 process, these independent housing estimates were compared to aggregate counts of addresses from the Master Address File to identify potential trouble spots. A second expansion of the DA program included the use of DA sex ratios to correct for correlation bias in the survey-based estimates (A.C.E. Revision II).

Strengths and Limitations of DA

Looking forward to 2010, how can DA play a more active integrated role in census planning and coverage measurement operations? The particular use of DA will depend on how we can minimize its limitations and more clearly maximize its strengths. In the following review, we identify where the strengths or limitations have changed to build a stronger case for the integration of DA. Our vision is a system where demographic analysis methods can provide important evaluation tools to inform and improve the census and coverage measurement results throughout the decennial process. In other words, DA is no longer a "national-only" and "once-in-a-decade" program with results available only after the census is over.

We review the following strengths and limitations:

Strengths of DA:

1. Low Cost
2. Operational Feasibility
3. Timeliness
4. Internal Consistency
5. Historical Benchmarks

Limitations of DA:

1. Lack of Geographic Detail
2. Limited Race/Ethnic Detail and Inconsistent Classifications
3 . The Immigration Component
4. Lack of Uncertainty Measures for the DA Estimates

The Strengths of DA in an Expanded Program

Demographic analysis has certain advantages over the survey-based approach that can be utilized in a

comprehensive integrated system.

1. **Low cost**.--Relative low cost makes the DA program very attractive. DA draws extensively from the Census Bureau's ongoing population estimates program and it requires no field operations to collect the data. Even with a stepped-up research program, the DA method is many times less expensive than the survey-based approach.

2. **Operational feasibility.**--The DA method is battle-tested in previous censuses, with continued improvements in data and techniques and results available for review. Since administrative data on births, deaths, legal immigration, and Medicare data are available and other components can be estimated, we face no operational "road blocks" in the production of demographic population benchmarks.

The traditional DA method for measuring coverage has been limited to national estimation. However, the administrative statistics on births, deaths, and Medicare are available at the State and county level. Immigration, emigration, and net internal migration are estimated as part of the Census Bureau's population estimates program. We have also developed a housing unit estimates program (for counties and places) which provides current housing benchmarks to complement the population estimates. Thus, the development of subnational population and housing benchmarks for the purpose of broad coverage evaluation is operationally feasible.

The expanded DA program also focuses on the consistency of key demographic and housing characteristics in the basic census data for geographic areas, such as the consistency of the age/sex distributions,
vacancy rates, and persons per household. The consistency check is operationally feasible as it draws on historical census data and the Census 2000.

3. **Timeliness**–Automation of census processing in 1990 and 2000 revolutionized the utility of DA as a timely coverage measurement tool. Since the demographic benchmarks are developed independently (field operations or census matching are not involved), we can have population and housing estimates in place by the time the first census files become available. In the past, the detailed census tabulations needed to produce the measures of coverage were never available until the census was final.

In 2000, aggregate addresses from the extracted Decennial Master Address File (DMAF) were available as early as the Fall of 1999 which made it possible to assess the completeness of the address file used to mail out questionnaires, plan and control field operations and to evaluate the number of addresses at the early stage of the census. Table 2 illustrates the housing benchmark approach. The July 1999 DMAF extract served as the control file for the field and processing operations associated with the census. As shown in Table 2, nationwide, the file started out with about 120.2 million addresses at the national level. This was 5.3 percent more addresses than expected given our benchmark of 114.2 million housing units. The differences varied by type of enumeration in the county.

Similar assessments were carried out throughout the census process. The final assessment of Census 2000 showed the final census housing count to be very close to the benchmark estimate overall. This finding is consistent with the national DA results which show the Census 2000 population to be very close to the expected population overall.

We can take full advantage of the timely capabilities of DA to conduct sequential analyses and "real-time" evaluation of the emerging census results. First, as shown above, independent housing unit benchmarks provide clues about the completeness of the Master Address File even before the census begins. Second, DA population benchmarks can give preliminary early readings on the differential undercount. For example, does the undercoverage of Black adult men and Black children appear to be very high in the first available census counts? Is this confirmed by the indication from low sex ratios for Blacks (suggesting large relative undercounts of adult Black men). Does overall undercoverage appear to be disproportionately high in geographic areas with minority concentrations? Finally, examination of the early DA coverage indicators for anomalous results provides a check on the quality of the DA measures themselves.

Table 2. Difference Between the Initial DMAF Housing Unit Count and the Housing Unit Estimate for the Nation and for Counties by Type of Enumeration Area: July 1999

	National	≥ 95% TEA=1	TEA=2	TEA=1+2	TEA=Mix
DMAF	120,244,120	67,077,859	5,299,753	29,731,561	18,134,947
Benchmark	114,226,276	63,140,457	5,123,093	28,281,404	17,681,322
Diff.	6,017,844	3,937,402	176,660	1,450,157	453,625
% Difference	5.3	6.2	3.4	5.1	2.6
Counties	**3,142**	**391**	**818**	**1,302**	**631**

Note: One county changed type of enumeration code between the initial DMAF and final Census. The category ≥ 95% TEA = 1 indicates counties in which at least 95 percent of the housing units were enumerated by mailout/mailback mode. TEA = 2 represents areas with update/leave enumeration.

4. **Internal Consistency**--The foundation of the demographic method is the logical and longitudinal consistency of the underlying demographic data. DA follows the process of population change as it occurs, starting with births, then incrementing or decrementing cohort size with subsequent information on mortality and net migration. The administrative data for DA is virtually complete (no samples involved) and available annually for the core components of births, deaths, and national Medicare enrollment (the immigration component is estimated based on administrative data combined with survey or census data). In fact, DA estimates of population are created every year as part of the ongoing population estimates program; it is only in years ending in "0" that they can be compared to the external census results (this ongoing nature of the estimates process relates to the low incremental cost of the DA program noted earlier).

The time series linkage of the DA estimates (for multiple censuses) provides a consistent basis to assess the plausibility of the demographic estimates themselves. On the other hand, the survey estimates have no direct longitudinal dimension and cannot check for both longitudinal and cross-section consistency.

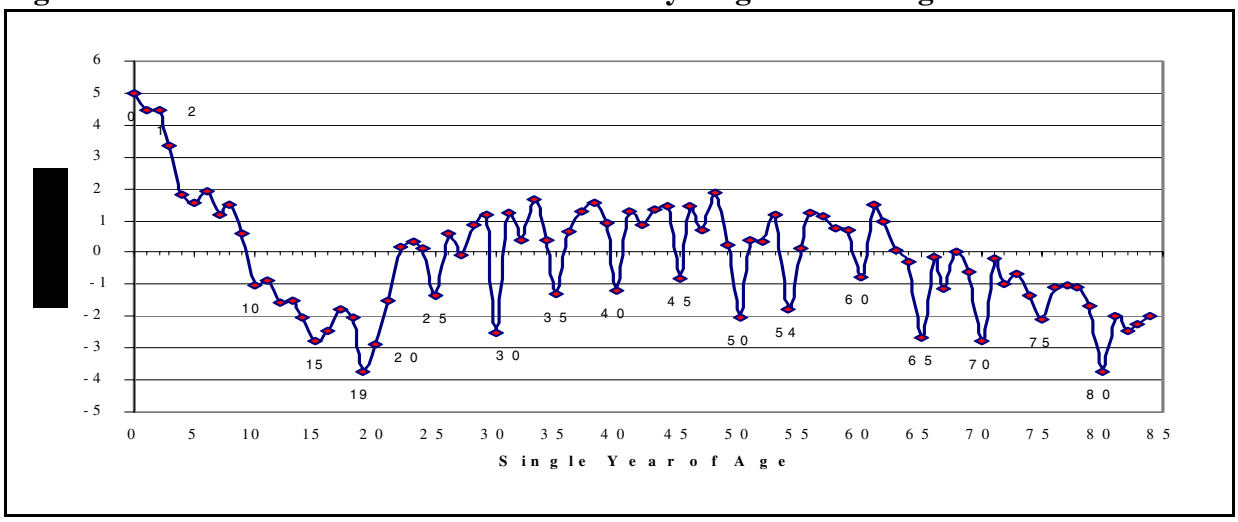
The demographic process automatically produces single-year of age estimates, which is a distinct advantage in evaluating the quality of age data in the census and assessing differentials in net undercount by age. The A.C.E. survey estimates are necessarily based on sample data, which because of the sample size, will compromise the quality of detailed age estimates. The differences in the Census 2000 and DA age distributions are vividly illustrated in Figure 3, which presents estimates of percent net undercount by single years of age (the net undercount represents the difference in the DA estimate and census count). While the overall net undercount in Census 2000 was only 0.12 percent based on DA, the differences by age are dramatic. A pattern of age misreporting (age "heaping") is conspicuous between ages 25 and 80 (5-year intervals). Two very different patterns are observed for ages under 22–one of relative large net undercounts at ages under 4 and another of relative large net overcounts between ages 10 and 21. The relatively large net overcounts at ages 19 and 20 are probably related to the double counting of college students at home and at school. We need to learn more about the sources of the undercounting of young children.

Because the estimates can only measure net undercount, interpretation is required about the possible contribution of undercounts and overcounts to cause the unique patterns of "nets" shown in Figure 3. But these detailed estimates help increase our understanding of the twin forces of coverage and content error that affect the quality of the age data in the census and supplement the much broader survey-based age estimates.

The independence and internal consistency of the DA estimation process also allows us to check the survey-based coverage estimates; in particular, to assess the consistency of the age-sex results. For example, the biggest difference between the DA and initial 2000 A.C.E. estimates was the measured net undercount of Black men, especially Black males between the ages of 18 and 50. Whereas the DA estimates a relatively large net undercount of 8.3 percent for Black men 18-49, the initial A.C.E. measured a negligible rate of 0.1 percent (for a discussion of the DA and initial A.C.E. estimates, see Robinson and Adlakha, 2002).

Relative to the DA estimates, the A.C.E. clearly understated the net undercount of adult Black men–that indicates the well-known "correlation bias". That is, persons missed by the census are not being proportionately picked up in the survey interview, leading to an understatement of the measured undercount. This is not new–correlation bias (relative to DA) is consistently found in the results of coverage measurement surveys in previous censuses. To address this persistent problem, the revised A.C.E. estimates incorporated an allowance for correlation bias by using the sex ratios based on DA; specifically, the A.C.E. Revision II estimates for males were derived by applying the DA sex ratios (separately for Blacks and Nonblacks) to the A.C.E. estimates for females (the estimates for females were assumed to be unbiased).

Figure 3 DA Percent Net Census Undercount by Single Year of Age: 2000



The adjustment for correlation bias raised the total A.C.E. estimate by 1.7 million, from a net overcount of 1.09 percent without adjustment to a net overcount of 0.48 percent with adjustment for correlation bias (see Table 1). The revisions were most dramatic for Black men, raising the net undercount estimate for Black males aged 18-49 from 0.1 percent (initial A.C.E.) to 7.5 percent (A.C.E. Revision II). The incorporation of the DA sex ratios represents the first time that the DA and coverage measurement survey results were used together.

6. **Historical benchmarks**--A major goal of the 2000 census was to reduce the differential undercount. The DA estimates provide the only consistent historical series of detailed age-sex-race undercount rates to document the change of net undercount in 2000 compared to earlier censuses. The survey estimates do not have this broad historical dimension. Further, the detailed 1990 PES estimates for Blacks are compromised for the purposes of making valid 1990-2000 comparisons (e.g., the PES estimates have not been adjusted for correlation bias, while the 2000 A.C.E. have been adjusted.)

Although this assessment of coverage trends can be most completely carried out at the national level (see Figure 1 for the 1940 - 2000 benchmark trends), we can also make some crude assessment of change in coverage for broad subnational areas using independent analytic techniques. For example, DA benchmarks were used to corroborate the significant reduction in net undercounts from 1990 to 2000 measured by the national DA results and the A.C.E. Revision II estimates (Adlakha et al, 2003). We compared coverage levels in 1990 and 2000 implied by a variety of different data sources: Medicare data to assess relative coverage of the population 65 and over; school enrollment data to infer relative coverage of the population aged 7 to 14, and birth statistics and migration estimates to assess relative coverage of the population under age 10.

In the use of school and Medicare enrollment data as benchmarks, the underlying assumption is that the coverage of these benchmarks (in 1990 and in 2000) has not changed over time. Thus the change in the school enrollment ratio and Medicare enrollment ratio (2000 compared to 1990) can be used to infer change in the census coverage. The results indicate the net population coverage improved from 1990 to 2000 for the nation and its regions. These findings are consistent with the national DA results and add geographic context.

For a final illustration of the utility of specific subnational DA benchmarks to assess coverage trends, we developed illustrative coverage indicators of ages 0-9 (young children) for States in the 1970-2000 censuses. The measurement of undercoverage of young children is a focus for two reasons: (1) Undercoverage is relatively high in these ages , and differentials by race are detected (mirroring that of the total population), (2) the development of subnational estimates for younger ages is more feasible than older ages because births are the single most dominant component of population change and the impact of error in measuring net migration for the total population is reduced for these age groups. The historical DA undercount rates for regions shown in Figures 4 and 5 provide pertinent information to document coverage differences for children.

Figure 4 DA Percent Net Undercount: Black Age 0-9: 1970 to 2000

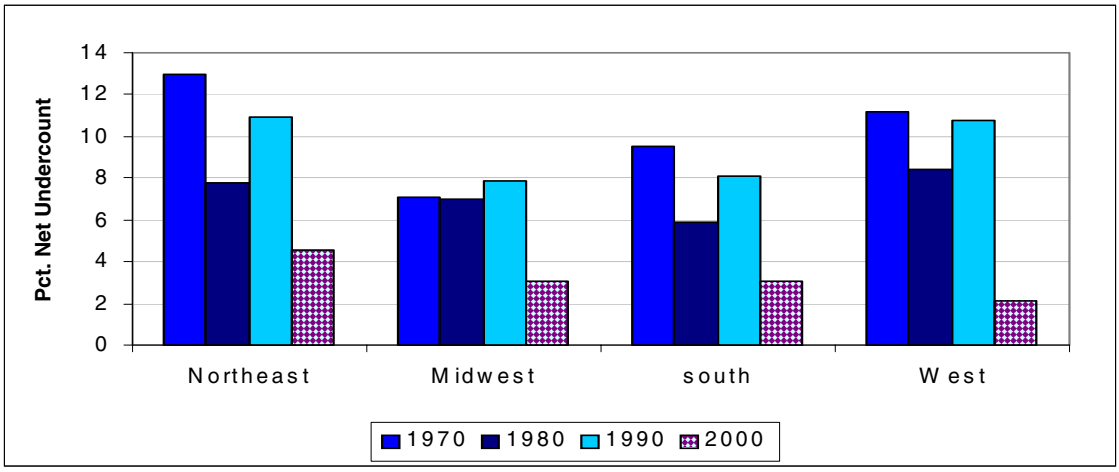
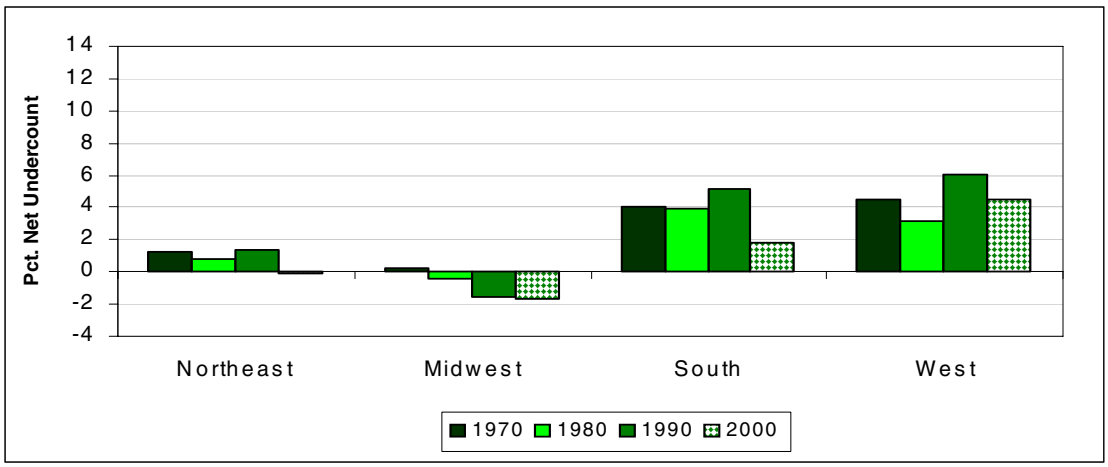


Figure 5 DA Percent Net Undercount: NonBlack Ages 0-9: 1970 to 2000



First, the estimates indicate that the undercount of Black children has been uniformly high in all regions of the country, and this pattern has persisted in every census (1970-2000). The lower net undercount rate for 2000 in all regions is consistent with the dramatic coverage improvement for the nation measured by the 2000 national DA estimates for Black children. Second, the lower net undercount rates for Nonblack children show a distinct regional pattern, with the rates being consistently higher in the South and West than in the Northeast and Midwest.

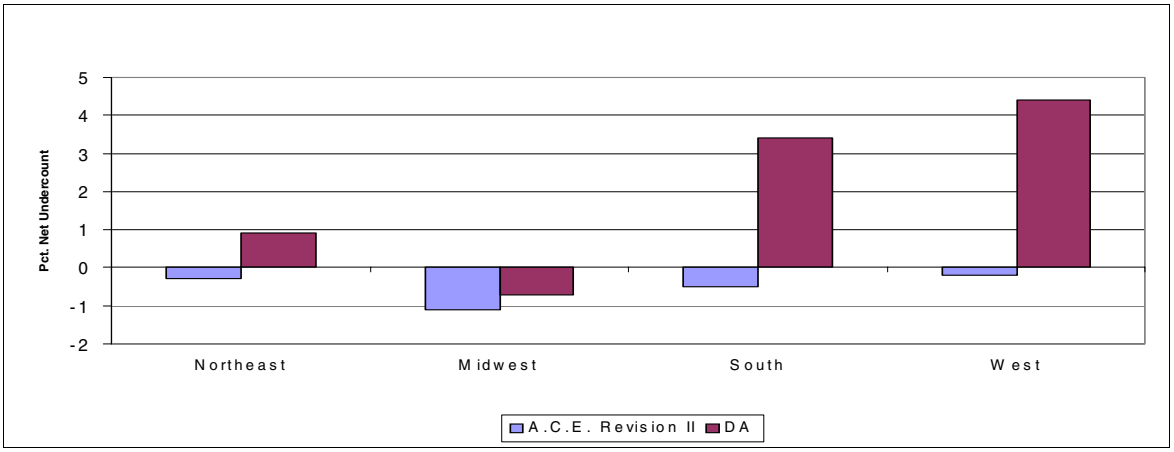
These benchmarks provide an important new geographic dimension to the demographic program, which can serve as a tool to evaluate the census and complement the survey-based coverage measurement activities. This is illustrated in Figure 6 where we compare 2000 A.C.E. Revision II results for ages 0-9 with the DA results for the regions. Similar to the national level results, the A.C.E. Revision II and DA results for children differ at the regional level: (1) the DA undercount rates for the regions are higher than the corresponding A.C.E. rates and (2) the DA shows a regional pattern–a higher net undercount in the South and the West than in the Northeast and the Midwest- which is not shown by the A.C.E. Revision II. We need to learn more about the reasons for the discrepant DA and A.C.E. results.

The Limitations of DA

In the previous section we have discussed the particular strengths of the DA benchmarks that can be exploited in developing an integrated coverage measurement program. These strengths must be balanced against certain limitations that are noted below.

1. **Lack of geographic detail**--Independent DA estimates in full age-sex-race detail are not available below the national level. For coverage measurement purposes in 2000, the survey-based A.C.E. estimates were designed to provide the subnational distribution of the net undercount.

Figure 6 Percent Net Undercount A.C.E. and DA Age 0-9: Census 2000



As noted previously, research has been conducted to develop "subnational" DA benchmarks of coverage which provide useful clues about broad patterns of coverage across geography or demographic groups and measures of change in coverage between censuses. Although these benchmarks are by no means definitive, they can give supplemental information on the quality of the census.

2. **Limited Race/ethnicity detail and inconsistent classifications–**The principal DA race categories are Black and Nonblack. Research is being conducted to produce DA estimates for Hispanics and Asians (as well as Non-Hispanic Whites), however, these estimates may not be as reliable as those for Blacks and Nonblacks. The coverage measurement survey would provide the coverage measurement standard for Hispanics, Asians, and American Indians (as well as important classifications by tenure).

The DA estimates of net undercount will be biased if persons who are classified as Black in DA are reported as another race in the census. We need to conduct more research to assess the degree of inconsistency and identify ways this "classification error" can be minimized. Also, the effect of the multiracial designation in the census race question for 2000 (mark one or more races) needs to be examined more carefully.

The issue of race classifications and implications of consistency with other data is addressed more fully in Snipp and Lott, 2003. The effect of alternative race classification on the DA estimates is discussed in U.S. Bureau of the Census, 2001b.

3. **Immigration Component--**Immigration is the weakest link in the components of the demographic accounting equation. While births, deaths, and Medicare data are based on administrative records that are available annually, the components of international migration (legal immigration, unauthorized immigration, emigration) must be estimated in large part.

For the initial DA estimates used to evaluate Census 2000, current administrative data were used to measure legal immigration flows. However, undocumented immigration and emigration were based entirely on estimation. Largely as a result of using extrapolations of past trends for the components, the initial DA estimate understated the growth of immigration during the 1990's which led to the DA underestimation of the total population. As described earlier, revised DA estimates included a revision of the immigration components based on examination of the Census 2000 data on the foreign-born. This reliance on the census data compromises the independence of DA as a coverage evaluation benchmark.

Given the growing contribution of immigration to population growth, it is imperative that the immigration estimates be improved and current data utilized. A potential source is the American Community Survey, which provides annual estimates of the foreign-born population from which estimates of net international migration can be derived.

4. **Lack of Uncertainty measures for the DA estimates**–A principal concern regarding the DA estimates is the uncertainty of the measured undercounts or overcounts. Without formal models to measure the uncertainty, we cannot answer questions like, "What is the confidence around the DA estimated net undercount of 0.12 percent in 2000", or "Is the difference in the DA estimate for Blacks (2.78 percent) and NonBlacks (-0.29) statistically significant?"

For the first time, the 1990 DA estimates were accompanied by statistically-based measures of uncertainty (Das Gupta, 1991). But these measures required subjective assessments of the range of uncertainty surrounding each of the underlying demographic components and assumptions about the distribution of the errors (e.g., normal, gamma), and the validity of these uncertainty models were questioned (see Clogg and

Himes, 1993). Given the lack of consensus about the approach to measuring DA errors and the fundamental differences in the census, DA, and A.C.E. estimates in 2000, the development of uncertainty estimates for DA is still on the research agenda.

The 2000 coverage evaluation experience, framed by the differences between the DA and A.C.E. estimates and the different sets within each method, again demonstrates that the estimated levels of net undercount are not precisely measured. However, it is important to note that the DA estimates are subject to less uncertainty in terms of measuring differences in coverage according to age, sex, and race. This property--that demographic analysis provides better measures of coverage differences rather than absolute coverage levels--is attributable to the fact that many of the errors in the estimates are consistent and hence tend to "cancel" in comparisons across sex, race, and time.

So, for example, the major patterns of coverage measured by the DA evaluation of Census 2000 stand out despite the difference in levels across sets (Base, Alternative, Revised): (1) net undercount in 2000 was substantially lower than in 1990, (2) the differential in coverage of Blacks and Nonblacks was reduced in 2000, and (3) the net undercount remains disproportionately higher than the overall average for only two groups measured by DA–black men and young children.

This particular strength of DA–that it provides more reliable measures of coverage patterns and differences between groups than absolute levels of coverage--can be exploited in an integrated measurement program. For example, the DA sex ratios (ratio of males to females) are less error-prone than the DA undercount estimates.

V. Discussion and Future Research

In designing a comprehensive integrated coverage measurement system for the 2010 census, we need to balance the strengths and weaknesses of DA and survey-based techniques. Clearly, demographic analysis should play an important role in the evaluation of the census operations and the coverage measurement estimates. The independent demographic estimates will be available on a timely basis to take multiple readings on coverage patterns, before, during, and after the census. And it can be done at a relative low cost.

The question is: How do we take the next step forward and formally integrate demographic analysis into the census and survey-based coverage measurement process? First, can the demographic benchmarks be used to make "real time" quality assessments during the census process (such as evaluate completeness of MAF and assess consistency of demographic distributions). Second, can we strengthen the coverage estimates in the areas where DA is strong and the survey-based estimates have been weak:--(1) the measurement of undercoverage of adult Black men and (2) the production of detailed estimates by age and sex that possess the demographic properties of longitudinal and internal consistency? By integrating the DA results into the survey estimates, the age-sex-race differences between the DA and survey estimates can be reconciled before and not after producing the final estimates.

We are developing a research agenda that will spell out how DA can be integrated in the census and coverage measurement process. This agenda also documents the research tasks needed to improve the basis for estimates themselves. Research topics include:

Use of Administration Records

The subnational DA approach uses a database developed internally at the Census Bureau, and known as the "Statistical Administrative Records System" or StARS. StARS consists of seven Federal databases that are merged, geocoded, reconciled, and converted into a "census-like" format. It was created in 1999, 2000 and is being recreated in 2002, and can be recreated on an annual basis.

The StARS 2000 database represents a highly detailed source of information that is ongoing and not (directly) dependent upon a decennial census or ongoing survey. The data in StARS 2000 are approximately concurrent with Census 2000, and contains similar content and structure. Person records include race, age, sex, and Hispanic origin, and are organized into housing units. Many of the StARS housing units have been matched to current Master Address File units and hence are geocoded to census blocks.

We have proposed two evaluations of the ability of StARS to contribute to Demographic Analysis. The first evaluation determines whether StARS can contribute to Demographic Analysis at the national level. This would involve comparing distributional results of the StARS 2000 and its components to Census 2000 and DA results. To the extent that DA and StARS 2000 results do not match Census 2000, an attempt would be made to develop calibration factors (analogous to coverage ratios) to assess the comparability of StARS with existing DA estimates.

The second evaluation drills down to lower levels of geography (e.g. counties), and attempts to use StARS data as a tool for estimating county level StARS-enhanced DA results from national DA estimates. After developing methods to allocate national DA results to counties using StARS data, these estimates will be compared to Census 2000 and A.C. E. and assessed for reasonableness and comparability.

Both research projects are necessarily exploratory, as we do not yet know exactly how the national DA results

compare to StARS 1999 or 2000. If the results are encouraging, we would propose a vigorous line of research and development to further solidify the relationship between the two programs.

Race and Origin Detail.

We are developing "experimental" demographic analysis estimates of coverage for the Hispanic and Non-Hispanic population under age 20 in 2000 based on demographic components of population change classified by origin over the period from 1980 to 2000. Estimates for the Non-Hispanic population classified by race (e.g., Non-Hispanic White, Asian) can be derived. Since historical components for Hispanic origin are not available nationally before the 1980's, other techniques are required to develop demographic-based estimates for origin groups for ages over 20 in 2000. The inconsistency of the race/origin classifications (census versus demographic component data) affects the reliability of the estimates.

The administrative StARS system may provide some information on race/origin estimation. As part of the analysis of StARS and DA linkages, these analyses would be followed by an attempt to use microdata linkages between StARS databases and existing DA databases in an attempt to provide race detail that is currently lacking. Again, this is an exploratory approach designed to discover if StARS can contribute to DA race detail.

Uncertainty

The problem of making statistically-principled statements about the uncertainty of DA estimates remains. Fortunately, the statistical community has been aware of these issues. Booker, et. al. (2000) and Berk, et. al. (2002) describe new approaches for developing uncertainty measures for what they call "complex computer models". These "complex computer models" are conceptually similar to DA models: A set of data are given as input to a model which consists of some dynamic transformation of the input data into output data.

The problem these researchers are addressing is: How does one associate uncertainty measures with the output data, given the dynamic nature of the model? We propose that the problem is entirely analogous to ours here. Their solution, embodied in PREDICT model described in Booker, et. al., is to use a combination of prior distributions on key model parameters, data (where available), data on similar system components (where available), and carefully elicited expert judgement. The PREDICT researchers combine these diverse sources of data in a fully Bayesian, statistically-principled way, so as to develop uncertainty measures around key model outputs. We propose further research on this approach be performed in the Census context, so as to take advantage of this approach to develop uncertainty estimates around DA results in an entirely analogous fashion.

Note: This paper reports the results of research and analysis undertaken by the U.S. Census Bureau staff. It has undergone a Census Bureau review more limited in scope than that given to official Census Bureau publications. This report is released to inform interested parties of ongoing research and to encourage discussion of work in progress.

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