An Evaluation of Population Estimates in Florida: April 1, 2000

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ABSTRACT

The housing unit method is the most commonly used method for making small-area population estimates in the United States and is widely used in other countries as well. These estimates are used for a variety of budgeting, planning, and analytical purposes in both the public and private sectors; consequently, detailed evaluations of their accuracy are essential. In this study, we evaluate the precision and bias of April 1, 2000 population estimates for counties and subcounty areas in Florida. We investigate the accuracy of several alternative techniques for estimating households and the average number of persons per household and the contribution of errors in each component of the housing unit method to total estimation error. We compare the accuracy of these estimates with several other sets of estimates, consider the role of professional judgment in the estimation process, and explore the impact of controlling one set of estimates to another. We believe this study provides further insights into the accuracy of small-area population estimates.

KEYWORDS

Demographic estimates, housing unit method, accuracy, estimation error, census data

The Bureau of Economic and Business Research (BEBR) at the University of Florida has made population estimates for all cities and counties in Florida each year since 1972. These estimates are made under the terms of a contract with the Florida Legislature and are used by businesses and government agencies for purposes such as monitoring growth trends, choosing optimal site locations, estimating the need for new schools and roads, determining eligibility for government programs, tracking emerging markets, and studying urban sprawl. They form the basis for distributing more than $1.5 billion each year to local governments through the State's revenue-sharing program. They even affect the salaries of some public officials. It is not surprising that these and other small-area estimates are of so much interest to so many people.

Given their central role in decision making, it is essential to evaluate the performance of small-area population estimates from time to time. In this paper, we describe the methodology used for making population estimates in Florida and—using a variety of data sources and techniques—compare the 2000 estimates with the results of the 2000 census. We also consider the role of judgment in making population estimates, look at two different approaches for making estimates that are consistent across several levels of geography, and compare the performance of the 2000 BEBR estimates with the performance of previous BEBR estimates and the 2000 estimates produced by the U.S. Census Bureau. This study not only provides further evidence regarding the accuracy of small-area population estimates, but also addresses several research issues that have received little attention in the empirical literature.

METHODOLOGY

BEBR uses the housing unit (HU) method to construct population estimates for cities and counties in Florida. This is by far the most commonly used method for making small-area population estimates in the United States. A 1990 survey of state and local agencies preparing population estimates found that 89% used the HU method, either alone or in combination with other methods (U.S. Bureau of the Census 1990). The HU method is widely used because it can be applied at any level of geography (e.g., states, counties, cities, census tracts, and blocks); can accommodate a variety of data sources and application techniques; and has often been found to produce reasonably accurate population estimates (e.g., Hodges and Healy 1984; Lowe, Myers, and Weisser 1984; Smith 1986; Smith and Mandell 1984; State of New Jersey 1984). The U.S. Census Bureau recently adopted the HU method as its sole methodology for producing subcounty population estimates in the United States (U.S. Census Bureau 1998).

The HU method is based on the assumption that almost everyone lives in some type of housing structure. In this method, population can be estimated as:

$$P_t = (H_t \text{ x } PPH_t) + GQ_t$$

where P_t is the population at time t, H_t is the number of occupied housing units (i.e., households) at time t, PPH_t is the average number of persons per household at time t, and GQ_t is the group quarters population at time t. Estimates of the group quarters population typically include persons without permanent living quarters (e.g., the homeless population).

This is an identity, not an estimate. If these three components were known exactly, the total population would also be known. The problem, of course, is that these components are almost never known exactly. Rather, they must be estimated from various data sources, using one or more of several possible techniques. In this section we provide a brief description of the data and techniques used to estimate these components for counties and subcounty areas in Florida. More detailed descriptions of the HU method can be found in Murdock and Ellis (1991), Rives and Serow (1984), Smith (1986), Smith and Lewis (1980), and Siegel (2002).

Households. Households can be estimated using data sources such as building permits, certificates of occupancy, electric customers, telephone customers, property tax records, and aerial photographs. Because they are widely available and correlate closely with population change, building permits and electric customers are the most frequently used (U.S. Bureau of the Census 1983). These are the data sources we use in Florida.

The housing inventory for a city or county can be estimated by adding the number of building permits issued since the most recent census (net of demolitions) to the units counted in that census. Building permit data are available from the U.S. Department of Commerce, which collects them directly from cities and counties throughout the United States. The time lag between the issuance of a permit and the completion of a unit is assumed to be three months for single family units and ten months for multifamily units; these assumptions were based on surveys of developers in Florida.

Building permits are no longer issued for mobile homes. Consequently, mobile home data must be collected from sources such as tax appraiser files and vehicle registration data. In general, mobile home data are not as accurate as data for single family and multifamily units.

Combining building permit and mobile home data with housing data from the decennial census provides an estimate of the current housing stock. The next step in the process is to estimate the proportion of housing units occupied by permanent residents. The most effective way to determine current occupancy rates is to conduct a special census or sample survey. Given their high costs, however, such censuses and surveys are rarely conducted. A common procedure is simply to use the occupancy rates from the most recent decennial census (U.S. Bureau of the Census 1983). This is the procedure we follow in Florida.

The product of the housing stock and the occupancy rate (performed separately for each type of housing structure) gives an estimate of the number of households. There are several problems with this estimate. Time lags between the issuance of a permit and the completion of a unit vary from place to place and from year to year. The proportion of permits resulting in completed units is generally unknown. Occupancy rates may be going up or down. Data for mobile homes are often of poor quality (or completely non-existent). In addition, some places do not issue building permits or have gaps in the data series. In Florida, for example, building permit data for the 1990s were missing for at least one year in 172 of the state's 455 subcounty areas.

The second source of data avoids some of these problems. Active residential electric customer data are available for all cities and counties in Florida and are often of better quality than building permit data. Perhaps more important, households can be estimated directly from electric customer data, eliminating the intermediate steps of estimating time lags, completion rates, demolitions, conversions, and occupancy rates. We collect electric customer data from 53 electric power companies in Florida; the five largest serve about 80% of the state's population.

There are several ways to estimate the number of households from electric customer data. One uses the net change in customers as a measure of the net change in households (e.g., Starsinic and Zitter 1968). This approach is useful in many circumstances, but there is not always a perfect one-to-one relationship between permanent households and residential electric customers. Housing units may be occupied by seasonal or other non-permanent residents; master meters may serve more than one household; and separate meters may be installed for pumps, barns, and other non-housing uses. In addition, record-keeping and accounting procedures vary from one utility company to another.

These differences can be accounted for by forming a ratio of the number of households counted in the most recent census to the number of customers reported for the same date, and applying this ratio to the current number of customers. This is the approach we generally follow in Florida. In some instances, we adjust this ratio upward or downward to reflect the continuation of historical trends in the household/customer ratio. These adjustments are based on our judgment regarding factors that might cause this ratio to change over time (e.g., increases in seasonal housing units or changes in electric power company bookkeeping practices).

Our final estimates of households are not based on the same data sources and techniques for all places, however. Rather, we use our professional judgment to decide which sources and techniques are likely to be most reliable for each individual place. Sometimes we use electric customer data, sometimes we use building permit and mobile home data, and sometimes we take an average of the two. Our choices are determined by the apparent quality of the data series and any available information on shifts in demographic trends in the local area. We hypothesize that applying professional judgment will lead to better household and population estimates than can be obtained by mechanically applying the same data and techniques everywhere. We test this hypothesis later in this paper.

Persons per household. The second component of the HU method is the average number of persons per household (PPH). Although PPH remained relatively stable at the state and national level between 1990 and 2000, PPH trends varied considerably from place to place. Changes in county PPH values between 1990 and 2000 ranged from -9.2% to 4.5% in Florida and 2000 values varied from 2.13 to 3.09. Variations in PPH levels and changes over time are even greater for cities than for counties.

To estimate PPH for cities and counties, we developed a formula that combines the local PPH calculated in the most recent census, the national change in PPH since that census (as measured by the Current Population Survey), and the local change in the mix of housing units (single family, multifamily, mobile home) since the most recent census. We base local changes in PPH on national changes, but adjust them upward or downward depending on whether the initial PPH was higher or lower locally than nationally; on the average, declines are greater when initial levels are higher. We further adjust the estimates to account for changes in the local mix of housing units and the PPH for each type of unit calculated in the most recent census (multifamily units typically have substantially lower PPH values than single family units). This formula is described more fully in Smith and Lewis (1980). Again, we make some adjustments to the formula's estimates according to our professional judgment regarding factors that may affect PPH (e.g., increases in the Hispanic population may raise an area's PPH because Hispanic households are larger than non-Hispanic households, on average).

Group quarters population. Population in households is estimated by multiplying the number of households times the PPH. Population in households accounted for 97.6% of Florida's population in 2000, the same proportion as in 1990. The remainder of the population is persons living in group quarters facilities (e.g., prisons, nursing homes, college dormitories) or without traditional housing (e.g., the homeless). We refer to this residual as the *group quarters* (GQ) population.

We estimate the GQ population using a three-step procedure. First, we collect data on the number of persons living in major group quarters facilities on the same date as the most recent census. Second, we subtract the number of residents in these facilities from the total non-household population counted in the census, and form a ratio of the residual to population in households; we call this ratio the *GQ multiplier*. Finally, we apply this multiplier to the current estimate of the household population and add the direct counts of persons currently living in the major group quarters facilities.

EVALUATING PRECISION AND BIAS

We constructed estimates for April 1, 2000 for each incorporated city, each county, and the unincorporated balance of each county in Florida. We evaluated these estimates by comparing them with census counts for the same date. This comparison does not provide a perfect evaluation, of course, because census counts themselves are subject to error. Census errors may be caused by missed households, refusal to respond, recording errors, sampling errors, geographic assignment errors, duplication errors, coding and data-processing errors, and the incorrect imputation of missing data. Differences between estimates and census counts may therefore reflect errors in census counts as well as errors in the estimates. The decennial census is reasonably accurate for most places, however, and provides a widely used standard for evaluating population estimates. We refer to differences between estimates and census counts as estimation errors, but the reader is cautioned that they may have been caused by enumeration errors as well as by estimation errors.

We used five measures to evaluate the accuracy of the estimates. Mean absolute percent error (MAPE) is the average error when the direction of error is ignored. The proportions of errors less than 5% and greater than 10% indicate the frequency of relatively small and large errors, respectively. These are measures of precision, or how close the estimates were to census counts, regardless of whether they were high or low. Mean algebraic percent error (MALPE) is the average error when the direction of error is included. This is a measure of bias: a positive error indicates a tendency to overestimate, a negative error indicates a tendency to underestimate. Since a few extreme errors in one direction can change the sign of the MALPE, the proportion of estimates that were above the census count (%POS) was used as another measure of bias. These measures have often been used to evaluate the precision and bias of population estimates (e.g., Davis 2001; Harper, Devine, and Coleman 2001; Siegel 2002; Smith and Cody 1994).

Errors by Size and Growth Rate. Table 1 summarizes the errors for the 2000 county population estimates in Florida. The MAPE for all counties was 4.2%. Almost three-quarters of the errors were less than 5% and only one in ten was greater than 10%. The estimates displayed very little bias, as the MALPE was only 0.8% and errors were about evenly split between those that were too high and those that were too low.

(Table 1 about here)

There was a strong negative relationship between MAPEs and population size. MAPEs were largest for small counties, but declined steadily as population size increased. The MAPE for the smallest size category was more than three times larger than the MAPE for the largest category. There was a tendency for small counties to be overestimated and large counties to be underestimated, but the relationship between population size and the direction of error was fairly weak.

There was a U-shaped relationship between MAPEs and population growth rates. MAPEs were largest in the lowest growth-rate category, smallest in the second-lowest category, and slightly larger in each of the following two categories. Bias was also strongly related to growth rates. There was a clear tendency to overestimate the most slowly growing counties and underestimate the most rapidly growing counties.

Table 2 shows population estimation errors for subcounty areas (i.e., incorporated cities and unincorporated balances of counties). The MAPE for all subcounty areas was 10.4%, more than twice as large as the MAPE for counties. Almost half of the errors were less than 5%, but almost one-third were greater than 10%. It is clearly more difficult to develop accurate population estimates for subcounty areas than for counties. There was a slight upward bias in the subcounty estimates, as indicated by a MALPE of 2.4% and 51.2% positive errors.

(Table 2 about here)

Differences in population size and growth rate had the same impact on estimation errors for subcounty areas as for counties, but the patterns were more clearly visible for subcounty areas because of the larger number of observations and the greater variability in size and growth-rate characteristics. MAPEs declined from 48.3% for places with fewer than 250 residents to 3.0% for places with 100,000 residents or more. There was a slight tendency for estimates to be too high in small places and too low in large places, but this relationship was fairly weak.

Differences in population growth rates had a strong influence of errors. There was a clear U-shaped relationship between MAPEs and growth rates. MAPEs were smallest in places with small but positive growth rates and grew rapidly as growth rates deviated in either direction from those levels. MAPEs were just over 5% for places growing 0-25% during the decade, but were 42.0% for places losing more than 10% of their residents and 31.4% for places that more than doubled in population size. There was a strong tendency for estimates to be too high for places losing population and too low for rapidly growing places.

In order to account for potential interactions between population size and growth rates, we divided subcounty areas into nine groups based on three size categories and three growth-rate categories (Table 3). The same patterns observed in Tables 1 and 2 can be seen in Table 3. Within each size category, MAPEs had a U-shaped relationship with growth rates and %POS declined as growth rates increased. Within each growth-rate category, MAPEs declined as population size increased but measures of bias were found to be unrelated to differences in population size.

(Table 3 about here)

Based on these results and the findings reported in previous studies (e.g., Davis 2001; Harper, Devine, and Coleman 2001; Hodges and Healy 1984; Smith 1986; Smith and Cody 1994; State of New Jersey 1984), we draw the following conclusions regarding population estimation errors:

1) Precision generally increases as population size increases.

2) Precision generally declines as growth rates deviate (in either direction) from low but positive levels.

3) Bias is largely unaffected by differences in population size.

4) Bias is strongly affected by differences in population growth rates: Estimates tend to be too high for places that are losing population and too low for places that are growing rapidly.

Errors by Component. Which component of the HU method can be estimated most accurately? Table 4 shows that errors were smallest for PPH and largest for the group quarters population (GQ). For counties, MAPEs were 3.3% for PPH, 3.5% for households, and 19.1% for GQ; for subcounty areas, they were 5.1%, 10.2%, and 73.7%, respectively. There was a slight tendency for PPH estimates to be too high and household estimates to be too low. The proportion of small errors was highest for PPH and lowest for GQ, and the proportion of large errors was lowest for PPH and highest for GQ. Percent errors for GQ were large because they were often based on small numbers of people.

(Table 4 about here)

Several studies have found errors for households to be greater than errors for PPH (e.g., Lowe, Myers, and Weisser 1984; Smith and Cody 1994; Smith and Lewis 1983; Starsinic and Zitter 1968; State of New Jersey 1984). This most likely reflects the fact that growth rates are generally higher and more variable for households than for PPH (sometimes, much higher and more variable). Whereas PPH changed by less than 5% for most counties and subcounty areas in Florida, households often changed by 10%, 20%, 30%, or more. There was simply more potential for error in estimates of households than estimates of PPH.

For both counties and subcounty areas, errors for GQ were much larger than errors for households and PPH. Does this mean that GQ errors contributed the most to overall estimation error? One way to answer this question is to construct synthetic population estimates using a combination of estimated values and census values. We made estimates for counties and subcounty areas under three scenarios. The first combined estimates of households with 2000 census counts for PPH and GQ; the second combined estimates of PPH with 2000 census counts for households and GQ; and the third combined estimates of GQ with 2000 census counts for households and PPH. For each scenario, then, errors in the resulting population estimates were due solely to errors in the single estimated component. The results are shown in Table 5.

(Table 5 about here)

For both counties and subcounty areas, Scenario 1 had the largest MAPE, the most large errors, and the fewest small errors. Even with perfect estimates of PPH and GQ, errors in household estimates would have created population estimation errors averaging 3.3% for counties and 9.9% for subcounty areas (ignoring the direction or errors). With perfect estimates of households and GQ, errors in PPH estimates would have created population estimation errors averaging 3.1% for counties and 5.5% for subcounty areas (ignoring the direction of errors). Scenario 3 had the smallest MAPE, the most small errors, and the fewest large errors. Although GQ errors were much larger than household and PPH errors, they contributed relatively little to overall estimation errors because the group quarters population generally accounts for a very small proportion of total population.

Household Errors by Technique. Households are frequently estimated using symptomatic data series such as electric customers or building permits. They can also be estimated by holding past values constant or extrapolating historical trends. Which approach produces the most accurate estimates? We tested the following techniques:

1) **BEBR –** a judgmental estimate based on electric customer and/or building permit data and our evaluation regarding which data sources, techniques, and assumptions to use for each specific place.

2) **EC –** an estimate based solely on electric customer data, using the ratio of households to active residential electric customers at the time of the 1990 census.

3) **BP –** an estimate based solely on building permit and mobile home data, using the techniques described previously.

4) **CONSTANT –** an estimate based on the assumption that the number of households has not changed since the 1990 census.

5) **TREND –** an estimate based on the assumption that the linear change in the number of households between 1990 and 2000 was identical to the linear change between 1980 and 1990.

The results are summarized in Table 6. Household estimates based on electric customer data were more precise than those based on building permit data, particularly for subcounty areas. For both counties and subcounty areas, the EC estimates had smaller MAPEs, more small errors, and fewer large errors than the BP estimates. Similar results were found in tests of 1980 and 1990 estimates in Florida (Smith and Cody 1994; Smith and Lewis 1983) and in several other studies (e.g., Rives and Serow 1984; Starsinic and Zitter 1968). We have not seen any studies in which household estimates based on building permit data were found to be more precise than those based on electric customer data.

(Table 6 about here)

As noted previously, not all places in Florida have complete building permit data. We replicated Table 6 using only subcounty areas that had virtually complete building permit data for the entire decade of the 1990s (all counties had virtually complete data). Although the differences were smaller than those shown in Table 6, the EC estimates still had a smaller overall MAPE (9.0% vs. 9.9%), more small errors (55.5% vs. 50.9%), and fewer large errors (19.8% vs. 26.5%) than the BP estimates. Even under the most favorable circumstances, then, BP household estimates were less precise than EC household estimates.

The EC and BP household estimates both performed much better than CONSTANT and TREND. CONSTANT had large errors and a strong downward bias for both counties and subcounty areas, whereas TREND had large errors (especially for subcounty areas) but displayed inconsistent results with respect to measures of bias. These results show that symptomatic data (e.g., electric customers and building permits) provided much more accurate household estimates than simply extrapolating past trends or assuming that no change has occurred.

The BEBR estimates performed considerably better than estimates based on the CONSTANT and TREND techniques, for both counties and subcounty areas, with smaller MAPEs, higher proportions of small errors, and lower proportions of large errors. They also performed consistently better than the BP estimates. However, the performance of the BEBR estimates was very similar to that of the EC technique. BEBR had a slightly smaller MAPE than EC for county estimates, but a slight larger MAPE for subcounty areas. The similarity of results reflects the fact that, in many instances, the EC household estimate was the one chosen as the BEBR household estimate.

PPH Errors by Technique. The PPH estimates used in Florida were based on a formula combining the local PPH value observed in the most recent census, the national change in PPH since that census, and the local change in the mix of housing units since that census (Smith and Lewis 1980). In some instances, these estimates were adjusted to account for other factors expected to influence PPH. In contrast to this approach, PPH is frequently estimated by extrapolating past trends or holding values constant at previous levels (e.g., Starsinic and Zitter 1968; U.S. Census Bureau 1998). Which approach produces the most accurate estimates? We tested the following techniques:

1) **BEBR –** a judgmental estimate based on the local PPH value observed in the 1990 census, the national change in PPH since that census, the local change in housing mix since that census, and other factors expected to influence PPH.

2) **FORMULA –** an estimate based solely on a mathematical formula combining the local PPH value observed in the 1990 census, the national change in PPH since that census, and the local change in housing mix since that census.

3) **CONSTANT –** an estimate based on the assumption that PPH has not changed since 1990.

4) **TREND –** an estimate based on the assumption that the linear change in PPH between 1990 and 2000 was identical to the linear change between 1980 and 1990.

The results are summarized in Table 7. BEBR produced better PPH estimates than any of the other techniques, with the smallest MAPE and least bias for both counties and subcounty areas. In most instances, it also had higher proportions of small errors and lower proportions of large errors. The BEBR estimates were only slightly better than those derived from the FORMULA and CONSTANT techniques, however. Errors for BEBR and FORMULA were similar because—in most instances—BEBR estimates were based directly on the FORMULA estimates with little or no judgmental adjustment. Both techniques produced errors similar to CONSTANT because there was relatively little change in PPH between 1990 and 2000 for most cities and counties in Florida. All three of these techniques performed substantially better than TREND, especially for subcounty areas.

(Table 7 about here)

DISCUSSION

Application of Professional Judgment. Population estimates using the HU method can be based on several different combinations of techniques and assumptions. Some are strictly mechanical, whereas others incorporate the application of professional judgment. Which approach provides the most accurate estimates?

We can provide some empirical evidence on this question by comparing several alternative sets of estimates for places in Florida. One (BEBR) was derived from the techniques and data sources described previously but included adjustments based on our judgment regarding the best practices and procedures to follow for each county and subcounty area in Florida. The others were based on the mechanical application of specific techniques. EC was based on electric customer household estimates and the formula for estimating PPH. BP was based on building permit household estimates and the PPH formula. Both of these estimates used the GQ estimation techniques described previously. AVE was an average of the EC and BP population estimates. CONSTANT was based on the assumption that the population in 2000 would be the same as it was in 1990, and TREND was based on the assumption that population change during the 1990s would be the same as it was during the 1980s. The errors for these techniques are summarized in Table 8.

(Table 8 about here)

The BEBR estimates outperformed the other techniques according to every measure of precision and bias. For both counties and subcounty areas, BEBR had the smallest MAPE, the highest proportion of small errors, the lowest proportion of large errors, and the least bias of all the techniques. The differences were not always large, but the application of professional judgment consistently improved the accuracy of the population estimates. We conclude that—although reliable data series and sound estimation techniques are essential to the production of accurate population estimates—the application of judgment informed by knowledge of local population dynamics and data idiosyncrasies can play an important role as well.

Of the mechanical techniques, BP performed a bit better than EC for counties and EC performed a bit better than BP for subcounty areas. The average of estimates from these two techniques also performed well. For counties, AVE had a smaller MAPE than either EC or BP. For subcounty areas, the MAPE for AVE was smaller than for BP but slightly larger than for EC. We believe that averages of several estimates will be useful for many purposes because they include more information that can be contained in a single estimate and they reduce the chances of making large errors. Several other studies of population estimates and projections have found averages to perform well (e.g., Ahlburg 1999; Smith and Mandell 1984).

CONSTANT performed very poorly, with many large errors and a strong downward bias. TREND also performed poorly, but was not nearly as biased as CONSTANT. Similar results have been reported in several other studies (e.g., Davis 2001; Harper et al. 2001). We conclude that population estimates based on symptomatic data (with or without the application of professional judgment) will generally be more accurate and less biased than estimates based on the extrapolation past trends or the assumption that no change has occurred.

Top-down vs. Bottom-up. Two approaches can be followed when making population estimates that are consistent across several levels of geography (e.g., subcounty, county, state). One is to adjust estimates for subareas so that they add exactly to an independent estimate of the larger area in which they are located. The other is to calculate the estimate for the larger area as the sum of the estimates of its constituent subareas. We refer to these as top-down and bottom-up approaches, respectively. Both lead to estimates for which the whole is equal to the sum of its parts.

Which approach is better? Some analysts have concluded that the first approach is preferable because large areas can generally be estimated more accurately than small areas (e.g., Shryock and Siegel 1973, p. 728). Others have questioned this conclusion, pointing out that this does not necessarily imply that the *sum* of the estimates for small areas is less accurate than an independent estimate of the larger area (e.g., Smith and Mandell 1984).

To our knowledge, no empirical research has compared the accuracy of population estimates based on these two alternative approaches.

We can test these two approaches using the EC population estimates discussed previously (similar tests using BP data cannot be conducted because BP data were not available for all subcounty areas). We address two separate questions: 1) Are county estimates based on county-level data and assumptions more accurate than county estimates based on the sum of the estimates of subcounty areas? 2) Are subcounty estimates more accurate when controlled to independent county estimates than when left uncontrolled?

They results of the analysis are summarized in Table 9. The top panel shows errors for independent county estimates and county estimates based on the sum of subcounty estimates. The latter were slightly more precise, with a smaller MAPE, a larger proportion of small errors, and a smaller proportion of large errors. The MALPEs for the two estimates were identical, but the %POS was slightly larger for the county estimates based on the sum of the subcounty estimates. This evidence shows a slight advantage for the bottom-up approach, but the differences were very small.

(Table 9 about here)

The bottom panel shows errors for subcounty estimates. In the first set, the subcounty estimates were controlled to add to the independent county estimates; in the second, they were not controlled. Again, the differences between the two approaches were very small. The uncontrolled estimates had a slightly smaller MAPE and proportion of small errors, but the controlled estimates had a slightly smaller MALPE and proportion of large errors. The %POS was the same for both. For these estimates, then, controlling to independent county estimates had very little impact on subcounty estimates.

Both the top-down and bottom-up approaches can be used when making population estimates for two or more levels of geography. The Census Bureau currently uses both: It controls subcounty estimates to independent county estimates (top-down) but calculates state estimates as the sum of each state's county estimates (bottom-up). In terms of accuracy, the evidence presented in Table 9 shows very little difference between the two approaches. Similar results have been reported in several studies of population projections (e.g., Isserman 1977; Voss and Kale 1985). We believe that decisions regarding which approach to use when making population estimates for several levels of geography must rest on considerations other than expected levels of precision and bias (e.g., meeting legal mandates or achieving consistency between two independent sets of estimates).

Comparison with Previous BEBR Estimates. BEBR's 2000 population estimate for the state of Florida was 15,693,075, about 1.8% below the census count of 15,982,378. Previous BEBR estimates for the state as a whole were 1.6% above the census count in 1990 and 2.7% below the census count in 1980. At the state level, then, the 2000 error was considerably smaller than in 1980 but slightly larger than in 1990. The change in errors from negative in 1980 to positive in 1990 and back to negative in 2000 was most likely caused—at least in part—by changes in census undercount. Nationally, census undercount declined between 1970 and 1980, rose between 1980 and 1990, and declined again between 1990 and 2000. Because each set of estimates is based on data from the previous census, errors in census counts are built into succeeding estimates. Changes in undercount from one census to another therefore influence the size and direction of population estimation errors.

Table 10 compares errors for 2000 with errors for 1980 and 1990 for local areas in Florida. According to every measure of precision and bias, the 2000 estimates for counties and subcounty areas performed better than in previous years: MAPEs and the proportion of large errors were smaller, the proportion of small errors was larger, MALPEs were closer to zero, and the proportion of positive errors was closer to 50%. Whereas the 1980 estimates had a tendency to be too low and the 1990 estimates had a tendency to be too high, the 2000 estimates displayed virtually no bias. Viewed as a whole, these results imply that the HU methodology employed by BEBR has no systematic bias toward either overestimation or underestimation.

(Table 10 about here)

Why were the 2000 estimates more accurate than the 1980 and 1990 estimates? There are several possible explanations. Population sizes were generally larger and population growth rates were generally lower during the 1990s than in the two previous decades; both of these factors lead to greater estimation accuracy, on average. Data series may have become more reliable over time. The insights gained through an additional ten years of studying estimation methods, sources of data, and the dynamics of Florida population growth may have improved the quality of judgmental adjustments. Blind luck may have played a role as well. We cannot say for sure, but any (or all) of these factors may have contributed to the greater accuracy of the 2000 estimates.

Comparison with Other Estimates. How do BEBR estimates stack up against those produced by other agencies? To our knowledge, the only other agency making independent population estimates for all cities and counties in Florida is the U.S. Census Bureau (USCB). Some local governments make estimates for places in their own jurisdictions, but not for other places in the state. Several private data companies (e.g., Claritas) also produce small-area population estimates, but base them on city and county estimates produced by the USCB or state demographic agencies.

The USCB provides a good standard of comparison because it is the nation's premier demographic agency. It has been producing state and local population estimates for many years and has pioneered in the development of a number of methods and data sources. Under its current methodology, it makes county estimates using the Tax Returns (TR) method (formerly called the Administrative Records method). In this method, population estimates are based on data on births, deaths, Medicare enrollees, residents in group quarters facilities, foreign immigrants, and estimates of internal migration based on matching return addresses on federal income tax returns (U.S. Census Bureau 2001). County estimates are controlled to add to a national estimate and state estimates are calculated as the sum of county estimates for each state. Subcounty estimates are developed using the HU method and are controlled to add to the county estimates (U.S. Census Bureau 1998).

The USCB's population estimate for Florida on April 1, 2000 was 15,275,725, about 4.4% below the census count. This error was more than twice as large as the error for the BEBR estimate. A summary of BEBR and USCB errors for counties and subcounty areas in Florida is shown in Table 11. According to every measure, BEBR estimates were more precise and less biased than USCB estimates. For counties, USCB estimates had a MAPE of 5.5% compared to 4.2% for the BEBR estimates. USCB estimates also had a higher proportion of large errors and a smaller proportion of small errors. Perhaps most notable, the USCB estimates had a strong downward bias, as indicated by a MALPE of -5.1% and only 11.9% positive errors. The BEBR estimates, on the other hand, had virtually no bias, with a MALPE of 0.8% and a distribution of 34 positive errors and 33 negative errors.

(Table 11 about here)

For subcounty areas, USCB estimates had a MAPE of 16.1% compared to 10.4% for BEBR estimates. Again, USCB estimates had a higher proportion of large errors and a smaller proportion of small errors than BEBR estimates. USCB estimates showed mixed results regarding bias, with a MALPE of 4.2% but only 38.7% positive errors. This seemingly contradictory result occurred because places with overestimates had larger errors than places with underestimates, on average. BEBR estimates for subcounty areas showed a slight upward bias, with a MALPE of 2.3% and 51.2% positive errors.

Why were the 2000 BEBR estimates more accurate than those produced by the USCB? There are several possible explanations. First, the national estimate for 2000 was substantially below the 2000 census count; because the USCB's state and local estimates are controlled to its national estimate, errors at the national level carry over to subnational estimates. Second, the TR method used by the USCB for county estimates may not be as accurate as the HU method; several studies have reported smaller errors for HU population estimates than for TR population estimates (e.g., Smith 1986; Smith and Mandell 1984). Third, the USCB's application of the HU method relies solely building permit data, whereas BEBR's application uses both building permit and electric customer data. As shown in Table 6, electric customer data generally provide more accurate estimates of households in Florida than do building permit data. Finally, BEBR analysts most likely have a greater knowledge of Florida population data and trends than do USCB analysts.

This knowledge may help BEBR analysts correct data errors and spot unusual trends more readily than USCB analysts.

CONCLUSIONS

Florida is a difficult state in which to produce population estimates. Many places are very small; many are growing or declining rapidly; many have large numbers of temporary residents; and many are undergoing substantial changes in age, race, ethnicity, and other demographic characteristics. All these factors raise the degree of difficulty of making accurate population estimates. Although errors for some places (especially small places) were quite large, the HU method produced relatively precise, unbiased population estimates for most places in Florida.

This is not to say that further improvements cannot be made, of course. We are currently evaluating the use of regression models to improve PPH estimates (Smith, Nogle, and Cody 2002). This work is very promising: MAPEs for county PPH estimates derived from regression models were found to be 1.9% for 1990 and 1.8% for 2000, compared to 2.3% for 1990 and 3.3% for 2000 for the regular BEBR estimates. We are also exploring the possibility of developing regression-based PPH estimates for subcounty areas.

Other possibilities for improving the performance of the HU method could also be explored. Better data sources and techniques for monitoring changes in the number of mobile homes might lead to better estimates of housing units. Such improvements would be particularly important in rural areas, where mobile homes often constitute a substantial proportion of the total housing stock. Advances in remote sensing and GIS technology might also be used to improve housing estimates, especially in areas lacking good data from other sources (e.g., Lo 1986; Webster 1996). Developing indicators of changes in occupancy rates and seasonal residency patterns could have a substantial impact on the accuracy of household estimates. Data from the American Community Survey may prove to be particularly useful in this regard.

The HU method provides an excellent tool for producing population estimates, both in Florida and elsewhere. It is flexible in terms of data sources and estimation techniques, can be applied at virtually any level of geography, and has a proven track record. Research on new techniques and data sources will undoubtedly lead to further improvements in the accuracy of its estimates. We believe the HU method will become ever more widely used for the production of state and local population estimates, not only in the United States but in other countries as well (e.g., Simpson, Diamond, Tonkin, and Tye 1996).

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TABLE 1: Population estimation errors by population size and growth rate: Counties in Florida, 2000

Size-1990	N	MAPE	MALPE	%POS	Percent of Absolute Errors <5%	>10%
<10,000	5	7.0	4.4	60.0	40.0	20.0
10,000-24,999	15	6.3	1.8	66.7	53.3	20.0
25,000-49,999	11	4.9	1.8	72.7	81.8	18.2
50,000-99,999	7	3.7	0.4	42.9	71.4	14.3
100,000-249,999	14	2.7	0.1	42.9	85.7	0
250,000+	15	2.3	-1.3	26.7	86.7	0
Total	67	4.2	0.8	50.7	73.1	10.4
Growth rate 1990-2000						
0-15%	5	8.8	8.0	80.0	40.0	60.0
15-25%	25	3.6	2.7	72.0	80.0	40.0
25-50%	32	4.0	-1.2	34.4	75.0	9.4
50-100%	5	4.2	-3.4	20.0	60.0	0
Total	67	4.2	0.8	50.7	73.1	10.4

TABLE 2: Population estimation errors by population size and growth rate: Subcounty areas in Florida, 2000

					Percent of Absolute Errors	
Size-1990	N	MAPE	MALPE	%POS	<5%	>10%
<250	22	48.3	33.8	63.6	4.5	77.3
250-499	27	15.0	4.6	55.6	25.9	59.3
500-999	48	12.4	6.3	54.2	41.7	43.8
1,000-2,499	70	14.3	-0.2	48.6	32.9	55.7
2,500-9,999	117	7.5	0.4	57.3	43.6	27.4
10,000-24,999	73	4.8	0.4	58.9	63.0	17.8
25,000-49,999	34	5.3	-3.8	29.4	55.9	14.7
50,000-99,999	37	4.8	0.6	43.2	64.9	8.1
100,000+	27	3.0	-2.0	29.6	77.8	3.7
Total	455	10.4	2.3	51.2	46.6	32.3
Growth rate 1990-2000						
<-10%	32	42.0	42.0	100.0	6.2	90.6
-10-0%	44	12.6	12.6	95.5	15.9	59.1
0-10%	112	5.2	2.5	54.5	67.9	13.4
10-25%	116	5.3	-1.9	44.8	56.0	17.2
25-50%	98	7.4	-4.1	35.7	46.9	31.6
50-100%	40	12.4	-11.8	20.0	37.5	45.0
100%+	13	31.4	-1.1	23.1	7.7	61.5
Total	455	10.4	2.3	51.2	46.6	32.3

TABLE 3: Population estimation errors by size-growth category: Subcounty areas in Florida, 2000

Size-1990	Growth Rate	N	MAPE	MALPE	%POS	Percent of Absolute Errors <5%	Percent of Absolute Errors >10%
<1,000	<0%	29	41.2	41.2	96.6	10.3	89.7
<1,000	0-50%	58	8.6	-0.8	41.4	41.4	34.5
<1,000	>50%	10	36.8	2.2	30.0	10.0	80.0
1,000-9,999	<0%	38	15.5	15.5	97.4	13.2	63.2
1,000-9,999	0-50%	130	6.9	-1.4	46.9	50.0	26.2
1,000-9,999	>50%	19	20.1	-19.3	15.8	21.1	68.4
>10,000	<0%	9	12.7	12.7	100.0	11.1	55.6
>10,000	0-50%	138	3.8	-0.8	45.7	71.0	8.7
>10,000	>50%	24	6.4	-5.8	20.8	45.8	20.8
Total		455	10.4	2.3	51.2	46.6	32.3

TABLE 4: Population estimation errors by component: Counties and subcounty areas in Florida, 2000

	Component	MAPE	MALPE	%POS	Percent of Absolute Errors	
					<5%	>10%
Counties	Households	3.5	-1.4	26.9	70.1	3.0
	PPH	3.3	2.5	80.6	83.6	1.5
	GQ	19.1	3.3	49.3	20.9	58.2
Subcounty Areas	Households	10.2	1.5	41.5	49.2	25.1
	PPH	5.1	0.7	66.2	64.0	9.9
	GQ	73.7	33.7	57.4	32.1	62.6

TABLE 5: Population estimation errors under alternate scenarios: Counties and subcounty areas in Florida, 2000

Errors	Scenario	MAPE	MALPE	%POS	Percent of Absolute Errors <5%	 >10%
Counties	1	3.3	-1.4	25.4	73.1	3.0
	2	3.1	2.3	80.6	88.1	0.0
	3	0.8	-0.2	49.3	100.0	0.0
Subcounty Areas	1	9.9	1.4	40.9	51.0	24.0
	2	5.0	0.7	66.4	66.2	9.2
	3	1.7	0.0	34.3	92.7	3.3

Note: Scenario 1: Estimates for households, counts for PPH and GQ.
Scenario 2: Estimates for PPH, counts for households and GQ.
Scenario 3: Estimates for GQ, counts for households and PPH.

TABLE 6: Errors by technique for household estimates: Counties and subcountry areas in Florida, 2000

	Technique	MAPE	MALPE	%POS	Percent of Absolute Errors <5%	Percent of Absolute Errors >10%
Counties	BEBR	3.5	-1.4	26.9	70.1	3.0
	EC	4.1	0.6	44.8	74.6	9.0
	BP	4.6	-2.3	31.3	64.2	14.9
	CONSTANT	21.7	-21.7	0.0	1.5	95.5
	TREND	7.1	-0.3	46.3	38.8	17.9
Subcounty Areas	BEBR	10.2	1.5	41.5	49.2	25.1
	EC	9.8	1.4	43.7	49.2	24.6
	BP	13.0	2.5	44.6	43.1	32.7
	CONSTANT	29.6	-3.5	14.9	18.5	64.8
	TREND	37.1	18.4	50.3	25.5	52.7

TABLE 7: Errors by technique for PPH estimates: Counties and subcountry areas in Florida, 2000

	Technique	MAPE	MALPE	%POS	Percent of Absolute Errors <5%	>10%
Counties	BEBR	3.3	2.5	80.6	83.6	1.5
	FORMULA	3.6	2.9	83.6	83.6	3.0
	CONSTANT	3.4	2.6	82.1	83.6	1.5
	TREND	4.0	-3.7	9.0	67.2	0.0
Subcounty Areas	BEBR	5.1	0.7	66.2	64.0	9.9
	FORMULA	5.3	1.6	68.6	61.5	11.4
	CONSTANT	5.8	1.9	68.1	62.0	10.8
	TREND	8.5	-3.0	23.5	49.2	19.3

TABLE 8: Population estimation errors by technique: Counties and subcounty areas in Florida, 2000

	Technique	MAPE	MALPE	%POS	Percent of Absolute Errors <5%	Percent of Absolute Errors >10%
Counties	BEBR	4.2	0.8	50.7	73.1	10.4
	EC	5.3	2.9	64.2	56.7	16.4
	BP	4.9	0.3	59.7	56.7	11.9
	AVE	4.8	1.6	61.2	59.7	13.4
	CONSTANT	21.0	-21.0	0.0	1.5	92.5
	TREND	8.0	-2.0	40.3	37.3	28.4
Subcounty Areas	BEBR	10.4	2.3	51.2	46.6	32.3
	EC	11.8	3.3	54.0	42.1	35.7
	BP	13.5	3.6	53.1	40.3	38.5
	AVE	12.0	3.3	56.6	42.1	35.9
	CONSTANT	18.7	-12.9	16.5	19.8	64.3
	TREND	19.4	-2.6	44.5	27.3	52.6

TABLE 9. Top-down vs. Bottom-up: A Comparison of EC Population Estimates

County Estimates

	County level	Sum of Subcounty
MAPE	5.3	5.2
% < 5%	56.7	59.7
% >10%	16.4	14.9
MALPE	2.9	2.9
% POS	64.2	65.7

Subcounty Estimates

	Controlled	Uncontrolled
MAPE	11.9	11.8
% < 5%	42.3	42.1
% > 10%	34.4	35.7
MALPE	3.2	3.3
% POS	54.0	54.0

TABLE 10: Errors of BEBR population estimates, 1980, 1990, and 2000: Counties and subcounty areas in Florida

	Year	MAPE	MALPE	%POS	Percent of Absolute Errors <5%	Percent of Absolute Errors >10%
Counties	1980	5.4	-2.9	34.3	53.7	10.4
	1990	5.4	3.3	74.6	58.2	16.4
	2000	4.2	0.8	50.7	73.1	10.4
Subcounty Areas	1980	14.4	3.5	46.7	33.6	42.4
	1990	11.9	6.0	68.4	36.5	40.5
	2000	10.4	2.3	51.2	46.6	32.3

TABLE 11: BEBR and the U.S. Census Bureau: Population estimation errors for counties and subcounty areas in Florida, 2000

		MAPE	MALPE	%POS	Percent of Absolute Errors <5%	Percent of Absolute Errors >10%
Counties						
	BEBR	4.2	0.8	50.7	73.1	10.4
	U.S. Census Bureau	5.5	-5.1	11.9	62.7	14.9
Subcounty Areas						
	BEBR	10.4	2.3	51.2	46.6	32.3
	U.S. Census Bureau	16.1	4.2	38.7	35.8	39.1