Evaluating Population Projections—The Importance of Accurate Forecasting

ESRI 380 New York St., Redlands, CA 92373-8100 USA
TEL 909-793-2853 • FAX 909-793-5953 • E-MAIL info@esri.com • WEB www.esri.com

Evaluating Population Projections—The Importance of Accurate Forecasting

An ESRI White Paper

Contents **Page**

Evaluating Population Projections—The Importance of Accurate Forecasting

Introduction

The decennial census is a picture of the U.S. population as of *April 1 of the census year,* and every 10 years, the Bureau of the Census spends billions of dollars counting the United States population. The goal of the count is reapportionment, but the census also provides profiles for states, counties, metropolitan areas, cities, towns, and neighborhoods. This once-a-decade effort provides a benchmark of the U.S. demographic composition.

A 10-year snapshot of the population may be adequate for some policy-level decisions, but for many public and private organizations, the information becomes stale quickly. If we base our plans only on data from the decennial census, some interesting problems can occur such as the following:

- California's trends changed shortly after the 1990 Census. In 1990, California's population had increased to nearly 30 million after decades of rapid growth including a gain of more than 25 percent in the 1980s. One in four Californians was Hispanic. Projections based on historic change anticipated a continuation of the growth and diversification of California's population. Census 2000 showed that California's rate of population growth had actually slowed to almost one-half of the historical rate after 1990. Immigration continued, but internal migration flowed to Oregon, Washington, Colorado, and Idaho.

- In 1990, the area from Denver to Colorado Springs was just a scenic drive. Just south of Denver, only a few hundred homes dotted Interstate 25. But changes were coming. By the mid-1990s, the C-470 highway connected undeveloped land in Douglas County and Denver, providing the spur to residential construction. By 1996, homeowners had to incorporate Lone Tree City to manage the building boom, and Census 2000 confirmed that Douglas County, Colorado, was the fastest-growing county in the United States.

- Census 2000 noted the section of Atlanta, Georgia, that formerly housed the Atlanta Steel Mill as vacant and unoccupied. This area is in the downtown business district near several major transportation links. In October 2001, it was announced that a $200 million aquarium would be built there. Developers rapidly bought up the surrounding land for residential and commercial projects. In three years, the area was radically different from the Census 2000 snapshot.

Each census count is rife with similar changes that result in "inaccuracy over time." What does this mean? Funding for many government programs during the next decade is based on census results. Public agencies and private industries that plan revenue growth or cost management need a tested source for reliable information so they can respond correctly to changes that happen *after* the census.

For nearly 40 years, businesses from Fortune 500s to small companies in all industries have relied on ESRI's accurate small-area estimates of population, household, and income characteristics. ESRI is an industry leader in reviewing and processing census information as well as understanding and accurately updating the dynamic census geography and demographic trends. The company spends a great deal of time and money every year to gather and integrate fresh information with the latest census data to yield accurate annual statistics that describe U.S. demographics. This white paper will explain the accuracy of ESRI's forecasts and how ESRI uses this analysis to improve its data.

The Value of Demographic Forecasts—Matching the Numbers

Between 1990 and 2000, America underwent many changes. The technology explosion created new business centers in San Francisco, California; Boston, Massachusetts; and Austin, Texas. Aging baby boomers moved south and west. Some northeast urban populations increased as younger people moved into the cities.

By the time Census 2000 was taken, ESRI had tracked many shifts in historical population trends and completed its own 2000 U.S. population forecast of 274,520,639, which was projected from population estimates through 1999. The Bureau of the Census estimated the U.S. population to be 274,520,000 on April 1, 2000. After the massive effort to count the population, the Census Bureau released its new count of 281,421,906, representing a difference from both the Census Bureau's and ESRI's totals of –6.9 million or –2.44 percent. This margin of error is addressed later in this paper; however, it should be noted that at a fractional cost of the Census Bureau's effort, ESRI forecasted the U.S. population with almost 98 percent accuracy!

Explaining the Process of Accurate Forecasting

Forecasts are easy to process. You just take two data points and extrapolate the change to some future date. For the numerically challenged, it's that simple. Intrepid number crunchers may prefer to employ more information and complex techniques like time series analysis or logistic regression. What works best?

Technique alone does not guarantee accuracy. Forecast accuracy depends on the quality of the input data and the assumptions made about the course of future change. *There is no single method or technique that can improve accuracy.* You can look at available data to track demographic change, then select a technique that best applies this data. More complex methods require more data and more detailed assumptions about the course of future change. With forecasts, more isn't necessarily better; sometimes, it's just more.

The key to accurate forecasting lies in evaluating your data sources and applying the information to develop reliable forecasts. A population forecast involves the collection of necessary data, a sound statistical procedure to create the forecasts, and a comprehensive evaluative system. While often overlooked, evaluation is an imperative part of developing population forecasts. There are several approaches to evaluating demographic forecasts including[1]

- Examining the forecasts compared to historical patterns of population change
- Comparing the forecasts relative to other estimates or projections for the forecast area
- Submitting forecasts to knowledgeable persons in the forecast areas for assessment
- Performing sensitivity analyses by testing the effects of different methods and assumptions

[1] Murdock, Steve H., and David R. Ellis. 1991. *Applied Demography.* Boulder, CO: Westview Press.

- Comparing forecasts with known population values such as a census count

When practical, data analysts regularly and rigorously perform the first four trials on every series of updates to ensure the highest standards of accuracy and reliability. But the opportunity to perform the fifth test comes only once in a decade. After the release of Census 2000 data, ESRI assessed the quality of its 2000 population forecasts. The focus of this evaluation is the comparison of the ESRI 2000 population forecasts to the Census 2000 resident population counts.[2]

Comparing the ESRI Approach to Census 2000 Results

Let's start with a simple statement: *The ESRI 2000 population updates are not directly comparable to Census 2000 counts*. The key elements of geography, date, and definitions explain the discrepancy.

- **Geography:** Census geography changed dramatically between 1990 and 2000. ESRI's 2000 updates, based on 1990 Census geography, were first converted to 2000 geography to enable a direct comparison to Census 2000. ESRI used sophisticated mapping technology to create a cross-reference of 1990 geography to the new 2000 boundaries. The results showed 1990 neighborhoods growing and splitting into multiple neighborhoods.

- **Date:** The ESRI updates represent July 1, 2000. Census Day was April 1, 2000. Therefore, ESRI's 2000 forecasts were shifted to April 1 to facilitate a consistent and reliable comparison.

- **Definitions:** Many of the census statistical definitions changed between 1990 and 2000. Of particular importance to demographic evaluation, the definitions of housing units and specific group quarters facilities changed. The U.S. Census Bureau does not release the detailed data necessary to measure the effect of these differences from 1990 to 2000.

Understanding the Margin of Error

After adjusting to the Census 2000 geography and date stamp, ESRI's 2000 updates were ready for comparison to Census 2000 counts. Testing usually measures the average difference between counts and updates. The Panel on Small Area Estimates of Population and Income[3] recommends measures of accuracy that include

- Low average error
- Low average relative error
- Few extreme errors/outliers
- Absence of bias[4]

What is a low error? Several rules of thumb guide the evaluation of population forecast accuracy. First, the magnitude of the error is *inversely* related to the size of the

[2] The terms *population estimate, population projection,* and *population forecast* are frequently confused. A population estimate may be made for any point in time. A population projection, on the other hand, is a conditional statement based on the outcome of a particular set of assumptions regarding the components of future population trends. A population forecast is the projection that an analyst believes is the most likely to provide an accurate prediction of the future population. Whereas projections are nonjudgmental, forecasts are explicitly judgmental. They are unconditional statements that reflect the analyst's views regarding the optimal combination of data sources, projection techniques, and assumptions. As such, a forecast represents a *type* of population projection. Because projections are, by definition, illustrative and not predictive, they cannot be proven right or wrong by future events.

[3] Panel on Small Area Estimates of Population and Income. 1980. *Estimating Population and Income of Small Areas.* Washington, DC: National Academy Press.

[4] Bias is defined here as the prevalence of over- or underestimates in an estimate series.

population—the smaller the population, the larger the error. By population size alone, lower errors are expected for states than for counties. In fact, an error of 5 percent or more at the state level is considered high. By extension, an error of 10 percent or more at the county level is considered high. No conventions for census tracts and block groups exist because few demographers provide forecasts for census tracts or block groups, and even fewer, other than ESRI, are willing to release the results of their analyses. Looking at the size variation between geographies, the average population of a county is 89,600—compared to 4,300 for census tracts and 1,300 for block groups. An error of 1,000 people at the county level is an error of only 1 percent. An error of 100 people at the tract level is a 2 percent error. And an error of 50 people at the block group level doubles the error again to 4 percent. Errors may be expected to be somewhat higher at the tract and block group levels because the absolute error has more meaning as the geography being measured shrinks.

Second, a key point that most users forget is that *forecasts of rapidly changing populations are invariably less accurate than forecasts of stable population areas*. If no one moved into or out of an area, it would be easy to project the population each year. However, business closings or openings tend to change living habits. An example is the 1980 situation in Houston when many people left and few people moved in until Houston's economy stabilized. As a rule, a population loss or gain of 2.5 percent or more annually characterizes a less stable base for projection, with the error highest among the areas that lose population.

A third key factor is that the longer the forecast period, the greater the forecast error. Annual updates improve accuracy by including the most recent changes to the population base. Therefore, it is more accurate to forecast what will happen in one year rather than in five years.

To evaluate ESRI's success in meeting the goal of minimal error, several measures were used. The first was percent error, or the difference between the ESRI 2000 forecasts and Census 2000 counts. Percent errors were used to identify outliers, or extreme differences. Average percent error summarizes the relative differences by geography and measures both absolute percent error (Mean Absolute Percent Error [MAPE]) and algebraic differences (Mean Algebraic Percent Error [MALPE]). MAPE has several desirable properties including reliability, ease of interpretation, support of statistical evaluation, and utilization of most of the information about error.[5] MALPE serves as a good measure of bias because it preserves the direction of the error, either positive or negative.

Update Accuracy

As expected, errors are reduced as the geography level increases. As shown in table 1, the smallest difference of 2.45 percent is evident for the United States; the largest, 8.9 percent, is reported for block groups. Within geographic levels, the variation by population size continues. Block groups with fewer than 500 people have the highest levels of forecast error (more than 20 percent); block groups with a higher population base of more than 1,000 display less than one-half of the error level of the small block groups. Of course, a difference of 20 is only 2 percent of a population of 1,000 but is 20 percent of a population of 100.

[5] Swanson, David, Jeff Tayman, and Charles Barr. 1999. "On the Measurement of Accuracy for Subnational Demographic Estimates." Paper presented at the U.S. Bureau of the Census Population Estimates Conference, June 8, 1999.

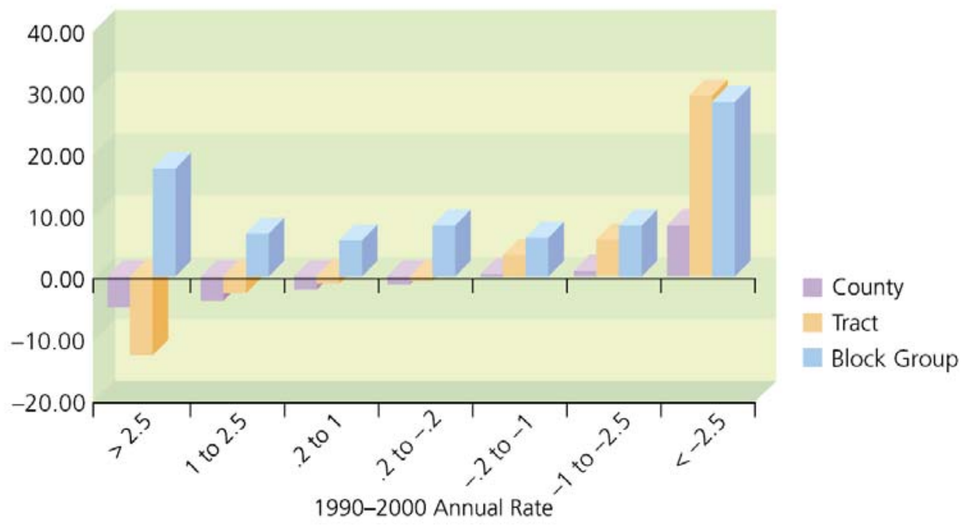
Table 1
Update Accuracy Summary by Geography

April 1, 2000	Mean Absolute Percent Error	Mean Algebraic Percent Error
U.S.	2.45%	–2.45%
State	2.66%	–2.66%
County	3.47%	–1.85%
Census Tract	6.80%	–1.20%
Census Block Group	8.87%	–0.80%

The variation is more pronounced by rates of change. The most elusive trend to track is the extreme loss of population that is more than 2.5 percent annually. Small areas cannot sustain the magnitude of a loss this size for any period of time, so the tendency is to reduce the rate of loss over the forecast period. Of course, a projected trend in population change cannot accommodate precipitous events like the closing of a military base or a prison, which can effectively drop the population to zero in a small area.

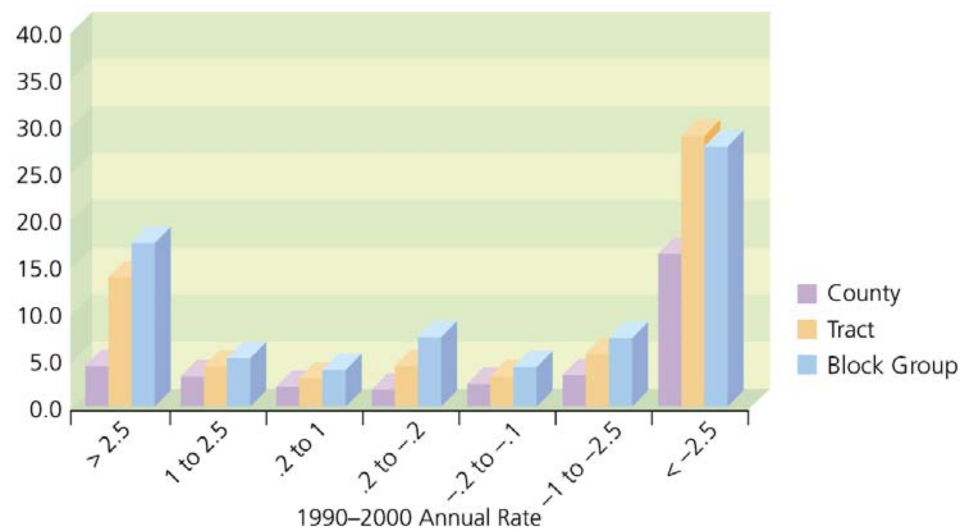
Demographic data and forecasting techniques are not the only factors that affect population change for very small areas such as block groups. Geographic accuracy is also critical. For example, if a prison was not located exactly according to block group coordinates in 1990 but was corrected in 2000, errors occur both in the original location and the corrected site. Offsetting errors in contiguous block groups are quite common, as evidenced by the algebraic error (MALPE), –0.8 percent for block groups and –1.2 percent for tracts. Figure 1 displays the average error by the annual rate of change from 1990 to 2000 and by geographic level.

Figure 1
MALPE by 1990–2000 Rate of Change and Geography



Extreme population growth is also a challenge to track. Again, few small areas can sustain extended periods of growth. When a small area is developed, the growth is immediate but short lived. The key to accurate forecasting is to target growth in areas that may change. Ninety percent of the block groups in 1990 changed at a slow-to-moderate pace; that is, less than 2.5 percent annually. Forecasts for these areas are accurate by any yardstick. Figure 2 displays the most stringent measure of forecast error, the absolute average, or MAPE.

Figure 2
MAPE by 1990–2000 Rate of Change and Geography



Trends in Update Accuracy

Before assessing what we learned from this test, we should compare our forecast testing to the 1990 Census. In 1990, the smallest areas for updates were census tracts and, in areas where tracts were not yet designated, minor civil divisions. The blocking of the United States and a consistent, hierarchical geography were introduced with the 1990 Census and TIGER, the first digital map of the country. Tests not only provide a snapshot of forecast accuracy at one point in time but also inform decisions about forecast data and methodology for the next decade. Did we learn anything from the 1990 test? Have we improved?

Table 2 shows the improvement in the accuracy of the updates at the county level. The forecast error for all counties decreased from 4.6 percent in 1990 to less than 3.5 percent in 2000. The enhancement of the updates through the 1990s is most pronounced among the smallest counties. Improvement is evident for all counties, regardless of population size. The negative bias also affects all counties, but the magnitude of bias is reduced by almost one-half from the positive bias in the 1980s. Figures 3 and 4 display the progress in tract forecasts from 1990 to 2000.

J-9633

Table 2
1990 and 2000 County Error by Population Size

MAPE	All	< 5,000	5,000 to 10,000	10,000 to 25,000	25,000 to 50,000	> 50,000
2000	3.5%	6.1%	3.9%	3.4%	2.9%	2.7%
1990	4.6%	8.8%	5.9%	4.6%	3.7%	2.9%
MALPE						
2000	–1.8%	–1.9%	–1.9%	–1.9%	–1.5%	–1.8%
1990	2.6%	5.5%	3.7%	3.0%	2.2%	0.8%

Figure 3
1990 and 2000 MALPE by Population Size by Tract

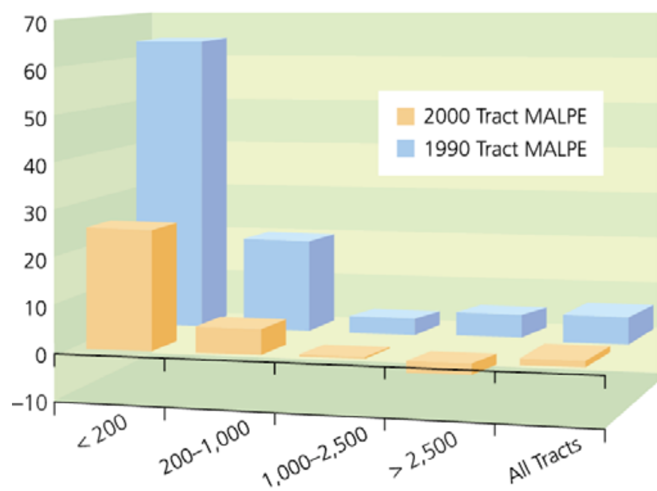
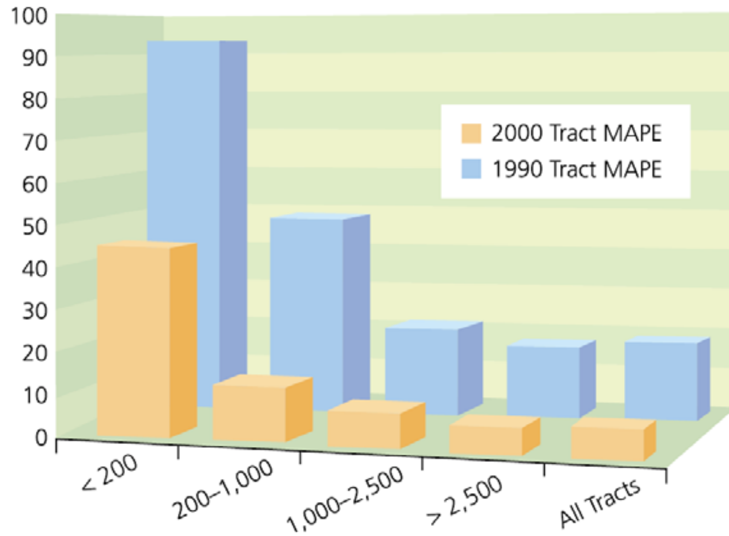


Figure 4
1990 and 2000 MAPE by Population Size by Tract



Lessons in Forecasting: Applying the Error

Testing provides a snapshot of forecast accuracy at one point in time, which is illustrative only at that point. Once the data and methodology are changed, the test becomes moot. The real goal of testing is adapting the lessons learned from past forecasts and improving the next generation of updates. Now we know that we did better than in the 1980s, but there's always room for improvement. The lesson is how to improve the numbers.

We began with the county updates. County population totals are used as controls for block groups and as the base for forecasting population characteristics. Improvement at the county level can lift the accuracy of all forecasts. To date, ESRI has used the Census Bureau's annual county population estimates, developed under the auspices of the Federal-State Cooperative Program for Population Estimates, with input and review from state demographers across the country. The current-year county updates, or forecasts, were based on the time series estimate available through the previous year. ESRI's 2000 updates were extrapolated from the Census Bureau's 1990–1999 population estimates that were released in March 2000.

Throughout the 1990s, the ESRI forecasts varied on average less than 1 percent from the estimates series. As of April 1, 2000, the official U.S. population estimate was 274,520,000. ESRI matched this with a national forecast of 274,520,639, which was projected from population estimates through 1999. However, the Census 2000 count of the U.S. population was 281,421,906, representing a difference from the Census Bureau and ESRI's totals of –6.9 million, or –2.44 percent (figure 5).

J-9633

Figure 5
Average Error by County: 2000

The difference between ESRI's updates and the Census 2000 count could be due to the method of extrapolating population change or the quality of the estimates series (table 3).

Table 3
Census 2000 Differences by State

State	April 1, 2000	April 1, 1990	Change 1990–2000	ESRI 2000 April 1, 2000	Difference
U.S.	281,421,906	248,709,873	13.2%	274,550,784	–2.44%
Alabama	4,447,100	4,040,587	10.1%	4,386,465	–1.36%
Alaska	626,932	550,043	14.0%	622,595	–0.69%
Arizona	5,130,632	3,665,228	40.0%	4,859,616	–5.28%
Arkansas	2,637,400	2,350,725	13.7%	2,561,435	–4.19%
California	33,871,648	29,760,021	13.8%	33,504,027	–1.09%
Colorado	4,301,261	3,294,394	30.6%	4,116,050	–4.31%
Connecticut	3,405,565	3,287,116	3.6%	3,289,015	–3.42%
Delaware	783,600	666,168	17.6%	759,727	–3.05%
District of Columbia	572,059	606,900	-5.7%	515,713	–9.85%
Florida	15,982,378	12,937,926	23.5%	15,277,566	–4.41%
Georgia	8,186,453	6,478,216	26.4%	7,910,517	–3.37%
Hawaii	1,211,537	1,108,229	9.3%	1,182,762	–2.38%
Idaho	1,293,953	1,006,749	28.5%	1,266,035	–2.16%
Illinois	12,419,293	11,430,602	8.6%	12,168,506	–2.02%
Indiana	6,080,485	5,544,159	9.7%	5,968,302	–1.84%
Iowa	2,926,324	2,776,755	5.4%	2,874,571	–1.77%
Kansas	2,688,418	2,477,574	8.5%	2,667,458	–0.78%
Kentucky	4,041,769	3,685,296	9.7%	3,981,006	–1.50%
Louisiana	4,468,976	4,219,973	5.9%	4,381,906	–1.95%
Maine	1,274,923	1,227,928	3.8%	1,256,496	–1.45%
Maryland	5,296,486	4,781,468	10.8%	5,201,930	–1.79%
Massachusetts	6,349,097	6,016,425	5.5%	6,201,776	–2.32%
Michigan	9,938,444	9,295,297	6.9%	9,892,128	–0.47%
Minnesota	4,919,479	4,375,099	12.4%	4,808,872	–2.25%
Mississippi	2,844,658	2,573,216	10.5%	2,782,958	–2.17%
Missouri	5,595,211	5,117,073	9.3%	5,492,512	–1.84%
Montana	902,195	799,065	12.9%	883,572	–2.06%
Nebraska	1,711,263	1,578,385	8.4%	1,669,846	–2.42%
Nevada	1,998,257	1,201,833	66.3%	1,858,827	–6.98%
New Hampshire	1,235,786	1,109,252	11.4%	1,212,402	–1.98%
New Jersey	8,414,350	7,730,188	8.9%	8,180,791	–2.78%
New Mexico	1,819,046	1,515,069	20.1%	1,744,753	–4.08%
New York	18,976,457	17,990,455	5.5%	18,217,799	–4.00%
North Carolina	8,049,311	6,628,637	21.4%	7,732,971	–3.93%
North Dakota	642,200	638,800	0.5%	631,220	–1.71%
Ohio	11,353,140	10,847,115	4.7%	11,271,043	–0.72%
Oklahoma	3,450,654	3,145,585	9.7%	3,377,155	–2.13%
Oregon	3,421,399	2,842,321	20.4%	3,342,534	–2.31%
Pennsylvania	12,281,054	11,881,643	3.4%	11,983,579	–2.42%
Rhode Island	1,048,319	1,003,464	4.5%	992,289	–5.34%
South Carolina	4,012,012	3,486,703	15.1%	3,923,528	–2.21%
South Dakota	754,844	686,004	8.5%	734,014	–2.76%
Tennessee	5,689,283	4,877,185	16.7%	5,522,397	–2.93%
Texas	20,851,820	16,986,510	22.8%	20,307,625	–2.61%
Utah	2,233,169	1,722,850	29.6%	2,152,170	–3.63%
Vermont	608,827	562,758	8.2%	595,862	–2.13%
Virginia	7,078,515	6,187,358	14.4%	6,925,526	–2.16%
Washington	5,894,121	4,866,692	21.1%	5,809,319	–1.44%
West Virginia	1,808,344	1,793,477	0.8%	1,804,535	–0.21%
Wisconsin	5,363,675	4,891,769	9.6%	5,268,064	–1.78%
Wyoming	493,782	453,588	8.9%	479,019	–2.99%

Because the differences between the Census Bureau's 2000 estimates and its Census 2000 counts parallel ESRI's forecast error at the county level, we assume that the problem is the input data. During the 1990s, the Census Bureau changed its county estimate methodology. Whether that change induced the negative bias is a question for the Census Bureau to address. It is likely that other factors, such as the difficulty of tracking rapid growth from immigration, had a negative effect on the estimates. Census 2000 results indicate more immigration to the United States in the 1990s than was officially documented. The Census Bureau's estimate series cannot be changed, but its estimates can be applied more selectively in the future. To date, ESRI has tested several alternative sources for population estimates that can be used to assess the quality of input data in future updates.

The negative bias that affected county updates was not evident at the block group level. The mean algebraic percent error by block group was less than 1 percent. We can follow address changes by neighborhoods, but the assignment of change to a specific block was not always correct. The effect is clearly shown by offsetting errors among contiguous block groups.

Census 2000 also revealed significant discrepancies in the assignment of group quarters facilities between the 1990 Census and Census 2000. Aside from the revised definition of noninstitutional group quarters, it appeared that some facilities were placed incorrectly in 1990 or 2000. Closer inspection of aerial photographs and satellite imagery revealed incongruities like a football stadium where a prison was supposedly located in 1990. The effect in a large trade area is nominal; however, the impact on a block group's population can be significant. Because group quarters are part of the total population, incorrect placement increases forecast error.

The test of block group forecast accuracy highlights the challenge of assigning the population to the correct census blocks. Correcting the base data of census counts is hardly an option, but we can target demographic change by block group more effectively by refining our assessment of local population change and particularly the potential for change.

Summary: Testing the Future

Close scrutiny of the base and input data is critical to forecast accuracy. Our experience is especially important with the impending release of a unique new source of postcensus demographic estimates, the Census Bureau's American Community Survey (ACS). The ACS is a rolling survey of the U.S. population designed to provide postcensus estimates of population characteristics and ultimately will replace the long form of the decennial census questionnaire.

Begun in 1996, the ACS included 31 test sites in 2000. Full implementation (excluding group quarters population) occurred in 2005. In 2006, data was released for counties and places with populations of 65,000 or more. It will take five years to accumulate a sample size sufficient to report data for smaller areas such as populations under 15,000. By 2010, the Census Bureau expects to release data for all areas. ACS data includes the variables represented on the Census 2000 long form, although the definitions differ from Census 2000 questions.

Is this too good to be true? Before data from the ACS can be applied to update Census 2000 data, a comparison is necessary. Differences from Census 2000 data include fundamentals such as the definition of population and housing units, sampling and weighting schemes, and reporting. The ACS data is collected monthly from independent samples, not from a single survey conducted at one point in time. Therefore, data reported from the ACS is composed of two- to three-year averages. Additionally, residence reflects "current" status rather than "usual" place of residence. A two-month rule discounts population on short trips but includes seasonal populations like "snowbirds" who winter in sunny states. ACS data is not directly comparable to Census 2000 data.

The Census Bureau cannot summarize the differences between the ACS and sample data from Census 2000. ACS test sites and the Census 2000 Supplementary Survey only allow comparisons for the country, states, select counties, and tracts. For the country and states, differences range from statistically significant to minor, but differences exist even for the largest areas of analysis. Without a five-year average of ACS estimates for all areas, the extent of the differences at the county level, the tract level, or the block group level will never be known.[6]

Conclusion

The ACS may be able to inform estimates of the change in population characteristics from earlier surveys. But it cannot be compared to Census 2000 data, and the ACS does not provide current data on the size and distribution of the population. In summary, the ACS does not obviate the fundamental challenges of forecasting—tracking current population change and anticipating the course of future change. To meet these challenges, ESRI tests its forecasts against every decennial census.

Our evaluations have taught us several lessons:

- How to improve forecast accuracy—from an absolute error of 14.5 percent for the smallest areas, census tracts, in 1990 to 6.8 percent in 2000
- How to extend forecasts to even smaller areas, block groups, in the 1990s while maintaining an unparalleled accuracy standard of less than 10 percent
- How to apply the latest tools and technology to improve and extend our forecasts including the analysis of TIGER, introduced in 1990, and the application of geographic information system tools through the introduction of improved input data from ACS
- How to differentiate—and anticipate—various patterns of population change from the influx of immigration to housing development at the block group level

ESRI carries the knowledge and expertise gained from the review of three censuses with its findings from Census 2000. We look forward to integrating all that we have learned and the tools now at our disposal in the next generation of forecasts. We have seen the future.

[6] For a discussion of the ACS, please see *The American Community Survey and the Data User Community*, an ESRI white paper.