A Review and Evaluation of the Housing Unit Method of Population Estimation

STANLEY K. SMITH*

The housing unit (HU) method is used by public and private agencies throughout the United States to make local population estimates. This article describes many of the different types of data and techniques that can be used in applying the HU method, and it discusses the strengths and weaknesses of each. Empirical evidence from four different states is provided, comparing the accuracy of HU population estimates with the accuracy of other commonly used estimation techniques. Several conclusions are drawn regarding the usefulness of the HU method for local population estimation.

KEY WORDS: Demographic estimates; Small area estimates.

1. INTRODUCTION

The housing unit (HU) method is the most commonly used method for estimating the population of small areas in the United States. According to recent surveys, between two-thirds and three-fourths of all agencies making substate population estimates in the United States use some form of the HU method (U.S. Bureau of the Census 1978, 1983a). Yet the HU method is more a general approach to population estimation than a specific set of techniques or procedures. There are many different techniques and types of data that can be used to make HU population estimates, and many different variations of the method are currently used. The proliferation of the HU method in recent years has been accompanied by a great deal of experimentation with new techniques and data sources, and a number of refinements have been made to improve the accuracy of population estimates. The availability of 1980 census results has made possible a substantial amount of new analysis of the errors found for HU population estimates. A review and evaluation of the current status of the HU method seems to be in order.

Section 2 describes the general framework of the HU method and discusses the strengths and weaknesses of a number of techniques and data sources that can be used in its application. Section 3 gives a number of examples of how the HU method is currently used throughout the United States to make local population estimates. Section 4 provides some empirical evidence regarding the accuracy of several different sets of HU population estimates, compared to the accuracy of alternate estimation techniques. Section 5 concludes with a number of observations regarding the usefulness of the HU method in making local population estimates.

* Stanley K. Smith is Associate Professor of Economics and Associate Director, Bureau of Economic and Business Research, University of Florida, Gainesville, FL 32611. A number of people made valuable contributions to different parts of this article. The author thanks Dick Engels, Shirley Goetz, Mary Heim, Ken Hodges, Bart Lewis, Theresa Lowe, Marylou Mandell, Ed Schafer, Paul Voss, two referees, and editor Joseph Kadane for their useful comments. He also thanks the U.S. Bureau of the Census for permission to use some previously unpublished data. An earlier version of this article was presented to the Small Area Estimation Workshop at the annual meeting of the Southern Regional Demographic Group in Orlando, Florida, October 17, 1984.

2. DATA AND TECHNIQUES

Virtually everyone lives in some type of housing structure, whether a traditional single family unit, an apartment, a mobile home, a college dormitory, or the county jail. This basic condition forms the foundation of the HU method. Within the framework of this method, the population of any given geographic area is equal to the number of occupied housing units (households) times the average number of persons per household (PPH), plus the number of persons living in group quarters (e.g., college dormitories, military barracks, nursing homes, prisons):

$$P_t = (H_t \cdot \mathrm{PPH}_t) + \mathrm{GQ}_t, \qquad (1)$$

where P_t = total population at time t, H_t = occupied housing units at time t, PPH_t = average number of persons per household at time t, and GQ_t = group quarters (GQ) population at time t.

This is an identity, not an estimate. If these three components were known exactly, the exact total population would also be known. The problem, of course, is that these components are almost never known exactly. They must rather be estimated from various data sources, using one or several different techniques. Many techniques and types of data can be used for estimating each component of the HU method, and each has its own characteristics with respect to precision, bias, and the distribution of errors. In this section I discuss a number of the techniques and data sources that can be used to estimate households, persons per household, and population in group quarters.

Number of Households

There are two major approaches to estimating the number of households. One relies on measures of construction activity, such as building permits or certificates of occupancy. The other uses utility data, such as residential electric or telephone customers. For purposes of exposition I focus on building permits and electric customers, the most commonly used types of construction and utility data.

Under the building permit approach, the number of housing units is equal to the number of units counted in the most recent census, plus the number of building permits issued since that census (adjusted to account for the time lag between the issuance of the permit and the completion of the unit), minus the number of demolitions. Households are then derived by applying an occupancy rate to this estimate of the housing stock:

$$H_t = (\mathrm{HU}_c + \mathrm{BP}_t - D_t)\mathrm{OCC}_t, \qquad (2)$$

where HU_c = housing units counted in the most recent census, BP_t = building permits (BP) issued between the most recent census and time t (adjusted for time lag), D_t = units reported

Journal of the American Statistical Association
June 1986, Vol. 81, No. 394, Applications

demolished between the most recent census and time t, and OCC_t = occupancy (OCC) rate at time t.

This is the simplest formulation of the building permit approach. Numerous refinements can be made to try to achieve more accurate estimates. One refinement is to disaggregate permits by type of unit. Single-family, multifamily, and mobile-home units have considerably different time lags between the date when building permits are issued and the date when units are ready for occupancy. Surveys conducted in Florida have shown that 3–5-month lags are common for single family units, whereas 10–20-month lags are common for multifamily units (Smith and Lewis 1980, p. 324). Mobile homes are typically ready for occupancy as soon as a permit is issued. The use of a single time lag for all types of building permits may therefore lead to inaccurate estimates of the number of new units being added to the housing stock.

Vacancy rates also differ considerably by type of unit. Single family vacancy rates are typically much lower than multifamily vacancy rates. In 1982, for example, U.S. vacancy rates were approximately 6% for multifamily units and 2% for single family units (U.S. Bureau of the Census 1983b, p. 14). For local areas, differences in vacancy rates by type of unit are often much larger than they are at the national level. The use of a single, overall vacancy rate may lead to significant errors if the mix of types of housing units has changed substantially since the most recent census.

To account for these potential errors, Equation (2) can be adjusted by distinguishing among different categories of housing units, such as single-family, multifamily, and mobile-home units. When housing units are differentiated by type, the number of households can be estimated as

$$H_t = \sum_i (HU_{ic} + BP_{it} - D_{it})OCC_{it}, \tag{3}$$

where i indicates the type of housing unit (e.g., single family, multifamily, mobile home).

Compiling building permit data by type of unit is simple but time-consuming. The data are available for both permits and demolitions for all areas that file Form C-404 with the U.S. Department of Commerce. It is estimated that approximately 90% of all new housing units in the United States are built in areas requiring building permits (Siskind 1980, p. 1). Places that do not issue building permits are generally small towns and sparsely populated rural areas. For places that issue building permits, the quality of the data is generally good. The primary exception is for mobile homes. Problems with building permit data for mobile homes include the issuance of permits for spaces in mobile home parks rather than for mobile homes themselves, double-counting for changes in ownership, and inadequate tracking of the movement of mobile homes from one site to another. In addition, some states do not issue building permits for mobile homes (e.g., New Jersey Department of Labor 1984). Building permit data for mobile homes are often of dubious quality.

Disaggregation by type of housing unit does not solve all of the problems inherent to the building permit approach, of course. Building permits are frequently issued for garages and additions to existing houses; such permits are sometimes mixed with permits for new units. Furthermore, building permits indicate the intention to build, not the reality of building. Some permitted units may be built immediately, some may be built only after a long delay, and some may never be built. Certificate of occupancy data can solve this problem, because certificates of occupancy are issued only when a unit is completed and ready to be occupied. Unfortunately, such data are not available for many places in the United States.

There are additional problems with the construction-activity approach to household estimation, regardless of whether building permit or certificate of occupancy data are used. The conversion of housing units from residential to nonresidential use is difficult to monitor. Demolitions are often underreported, sometimes by large amounts. Losses due to fire or severe weather may be substantial in some local areas. Housing units built for permanent occupancy generally cannot be distinguished from those built for seasonal or part-time occupancy. While some of these factors can be accounted for through the collection of detailed local data (e.g., Mindlin, Ahuja, and Kunen 1977), they can all potentially add to the imprecision of estimating housing units from building permits or certificates of occupancy.

Once the number of housing units has been established, an estimate of the current occupancy rate must be made. Occupancy rates are often estimated by assuming that current rates are the same as those observed in the most recent census. This assumption will generally yield good results when the time interval since the most recent census is short. As the time interval increases, however, occupancy rates become more and more subject to change. The reliability of estimates based on past occupancy rates thus declines over time.

Direct surveys or counts may be the best way to estimate current occupancy rates. In small places such surveys or counts can be conducted fairly easily, but in large places reliable surveys and complete counts are quite expensive. Consequently, they are seldom used. Postal vacancy surveys can be used to estimate occupancy rates for large places, but their usefulness is limited by a lack of correspondence between postal areas and municipal boundaries and by differences in definitions of permanently occupied units. A comparison of postal vacancy rates and census vacancy rates for a number of cities in Washington in 1970 showed census vacancy rates to be consistently higher than postal vacancy rates; the differences were often quite large (Lowe, Pittenger, and Walker 1977, p. 11). Recent work using a ratio of census vacancy rates to postal vacancy rates, however, has shown promising results for larger cities in which boundaries have remained constant over time (Lowe, Myers, and Weisser 1984, p. 9). It is possible that future research will point to useful ways to incorporate postal vacancy survey data into household estimation techniques for large cities (surveys are not conducted in small cities or towns).

Current occupancy rates can also be estimated by relating the number of active residential electric customers to the total number of residential customers (e.g., Tessmer 1976) or to estimates of total housing stock (e.g., California Department of Finance 1984). The first approach has yielded very accurate estimates, but it requires a substantial amount of effort and can be used only in areas with very detailed, high-quality customer data. The second approach has the additional problem of combining two different data series. If building-permit and electric-customer data are not consistent with each other, the resulting occupancy rates will not be useful.

Several researchers have concluded that better estimates of households can be made from electric utility data than from building permit data (e.g., Starsinic and Zitter 1968; Smith and Lewis 1980, 1983). Electric customer data are often of better quality than building permit data and are more likely to be available for all places. More important, households can be estimated directly from active residential customers. The intermediate steps of estimating time lags, completion rates, demolitions, conversions, and occupancy rates—necessary when estimating households from building permits—are eliminated.

There are several ways to estimate the number of households from active residential electric customers. One technique uses the net change in customers as an indicator of the net change in households:

$$H_t = H_c + (\mathrm{REC}_t - \mathrm{REC}_c), \tag{4}$$

where H_c = occupied housing units in the most recent census, REC_t = active residential electric customers (REC) at time t, and REC_c = active residential electric customers at the time of the most recent census. This technique assumes a one-to-one correspondence between changes in households and changes in active residential electric customers. Although this assumption may be accurate in many circumstances, there are a number of reasons why a perfect one-to-one relationship does not exist everywhere. Housing units used seasonally or held for occasional use may have active electric meters but not be occupied by permanent residents. One customer may represent many households if a master meter is present (i.e., one meter serving two or more households). Individual meters are often found for pumps, garages, barns, outdoor areas, and other types of residential but nonhousing use. These meters may appear on the records as separate customers. Bookkeeping practices of individual electric utility companies may differ in the handling of special cases (e.g., a business operating out of a private home may be classified as either a residential or a commercial customer). The geographic boundaries used by the electric power company may not correspond exactly to those used by the Census Bureau. In addition, there are still a few homes without electricity.

All of these factors can cause the number of active residential electric customers to differ from the number of households. In Florida in 1980, for example, the number of households was within 10% of the number of active residential electric customers in only one-half of all local areas. It was more than 25% different in almost one-sixth of all local areas (Bureau of Economic and Business Research 1983). These differences are undoubtedly larger in Florida than in most other states because of Florida's large seasonal population, but they are present to one degree or another in every state.

The lack of a one-to-one correspondence between households and electric customers makes a second estimating technique useful in many places:

$$H_t = (H_c/\mathrm{REC}_c)\mathrm{REC}_t. \tag{5}$$

In this technique the ratio of households to electric customers is calculated from data corresponding to the date of the most recent census. This ratio is then assumed to remain constant to the current estimation date. This technique is particularly useful in places where the ratio of households to electric customers is considerably different from 1.0, such as areas with a substantial number of seasonal residents.

The validity of the ratio technique rests on the assumption that the ratio of households to active residential electric customers remains constant. This ratio is subject to change over time, but it appears to remain quite stable in many places. A study of 1980 population estimates in Florida (Smith and Lewis 1983) found that the ratio technique [Equation (5)] provided more accurate household estimates than the technique based on a one-to-one correspondence between households and customers [Equation (4)].

A further adjustment to the ratio technique can be made by extrapolating the average annual change in the household/customer ratio observed between the two most recent censuses. This adjustment may be useful when the nature of a community is changing, such as when the seasonal population is rising steadily in relation to permanent population. Further empirical research is needed on the comparative accuracy of these techniques.

The quality of electric customer data can vary considerably from company to company. Large companies generally provide very accurate data, sometimes down to the subcity level (e.g., census tracts) and separately for different types of housing units (e.g., single family, multifamily, mobile home). Very detailed analyses can be performed with this type of data (e.g., Houston Chamber of Commerce 1976; Tessmer 1976; Walker and Davis 1981; Serow, Eberstein, Mayberry, and Rives 1984). In some instances, however, the quality of electric customer data is poor. Companies occasionally have problems distinguishing between active and inactive meters or between residential and commercial customers. A more commmon problem is the determination of the precise geographic location of electric meters. For example, some companies have no records indicating whether their meters are inside or outside the city limits. These and similar problems are most often found among small companies serving relatively few customers. In these circumstances, diligent monitoring of the data is required to ensure that household estimates are of acceptable quality.

The discussion thus far has dealt primarily with two major sources of data for household estimates: building permits (or closely related, certificates of occupancy) and electric customers. These are the most common types of data used in HU estimates, but other types can be used as well. Donnelly Marketing Information Services, a private company specializing in demographic data and research, makes household estimates for census tracts using telephone customer data and a ratio procedure similar to Equation (5) (Hodges and Healy 1984). Water and gas companies are other sources of utility data sometimes used for local estimates. The major problem with these data sources is that the correspondence between customers and households is generally not as close for telephone, water, and gas utilities as for electric utilities. Many households have no telephones or have unlisted numbers, draw water from private wells, use bottled gas, or have no gas appliances. Under these circumstances, changes in customers may reflect changes in coverage rather than changes in the number of households.

Administrative records such as property tax files, voter registration lists, and post office address lists can also be used as sources of housing or population information. These records differ a great deal from place to place, providing good data for some places and poor data for others. Consequently they must be evaluated independently for each place in which their utilization is being considered. My experience has been that these types of data generally do not provide useful estimates of households because they are not sufficiently up to date, they do not correspond to the same geographic boundaries as the area being estimated, or they cover only a particular segment of the population. In some localities, however, administrative records may provide very useful information. One of the most useful features of the HU method is that it can incorporate data from many different sources and utilize data sources unique to one or a few places without the requirement that identical data be available for all places.

Estimates of the number of housing units can also be based on aerial photographs. The major problem with aerial photography is determining the number of permanent housing units within each structure. This is relatively simple for single-family detached units, but it may be very difficult for duplexes, townhouses, and large multiunit structures. It may also be impossible to determine from aerial photographs whether a building or mobile home represents a housing unit rather than a garage, storage shed, commercial establishment, or some other type of nonhousing use. Aerial photography is expensive and time-consuming, and it is not widely used for estimating housing units.

Finally, the number of housing units can be estimated through a direct count. This is the most accurate way to estimate housing units, and it is a useful technique for very small places in which all units can be counted in a short period of time. For larger places, however, direct counts are generally not feasible because of the time and expense they require.

Seasonality poses what is perhaps the most difficult problem in estimating households, regardless of the data source. There is generally no way to determine whether a particular building permit, certificate of occupancy, or electric or telephone customer represents a permanent household or a nonpermanent housing unit (i.e., seasonal or held for occasional use). If the ratio of permanent households to nonpermanent units is changing over time, techniques based on a constant household relationship will produce inaccurate household estimates. Changes in this ratio can be measured through sample surveys, but they are generally too expensive to be feasible. Fortunately, most places have few seasonal units, and for many of the places that do have a substantial proportion of seasonal units, the seasonal component remains stable over time. In some places, however, changes in the number of seasonal units cause large errors in the estimates of permanent units. The development of effective indicators of changes in seasonality would greatly enhance the usefulness of the HU method.

Persons Per Household

A number of techniques can be used to estimate the average number of persons per household (PPH). The simplest is to use the PPH calculated in the most recent census:

$$\mathrm{PPH}_t = \mathrm{PPH}_c, \tag{6}$$

where PPH_t = the average number of persons per household at time t and PPH_c = the average number of persons per household in the most recent census. This technique provides relatively accurate estimates when the estimation date is close to the previous census, but it becomes increasingly unreliable as the years go by. Other techniques have been found to produce considerably more accurate estimates of PPH than simply using the value from the most recent census (e.g., Starsinic and Zitter 1968; Smith and Lewis 1983).

Another technique for estimating PPH relies on the linear extrapolation of the trend in PPH between the two most recent censuses:

$$\mathrm{PPH}_t = \mathrm{PPH}_c + x/y(\mathrm{PPH}_c - \mathrm{PPH}_{c-1}), \tag{7}$$

where PPH_{c-1} = the average number of persons per household in the second most recent census, x = the number of years between times c and t, and y = the number of years between times $c - 1$ and c. This technique will produce accurate estimates when PPH follows a stable trend, but it will become increasingly inaccurate as trends change. In the United States, PPH declined by 1.2% between 1950 and 1960, by 5.7% between 1960 and 1970, and by 12.1% between 1970 and 1980 (U.S. Bureau of the Census 1983c). Obviously, trends changed considerably from one decade to the next, and the simple extrapolation of past PPH trends under such circumstances would have led to inaccurate estimates for many places. A study of population estimates in Florida found that techniques incorporating data more recent than those from the previous census produced estimates of PPH that were considerably more accurate than the simple extrapolation of past trends (Smith and Lewis 1983).

A third technique for estimating PPH incorporates postcensal data as well as data from the most recent census. This technique is based on the local PPH in the most recent census and estimated PPH trends since that census:

$$\mathrm{PPH}_t = (1 + D_t)\mathrm{PPH}_c, \tag{8}$$

where D_t = the proportional change in PPH since the most recent census.

The proportional change in PPH since the most recent census (D_t) can be estimated in several ways. One way is to use the national or regional percentage change in PPH since the most recent census, as measured annually in the Current Population Survey. This approach can be refined by adjusting the percentage change in PPH upward or downward, depending on the level of the local area's PPH at the time of the most recent census. If the local area's PPH were larger than the national (or regional) PPH at the most recent census, the decline in PPH since that census could be made larger than the national (or regional) decline. If the local area's PPH were smaller, the decline in PPH could be made smaller. The rationale for this adjustment is that as PPH declines, the potential for further decline becomes weaker because there are levels below which PPH cannot fall. Theoretically, this lower bound is 1.0. In practice, the lower bound is most likely considerably higher than 1.0, and it will generally be higher for single family units than for multifamily units. Techniques for quantifying this adjustment were described by Smith and Lewis (1980) and Serow et al. (1984). A number of empirical studies have found that declines in PPH tend to be larger in places with a large PPH than in places with a small PPH (Findley 1979; Smith and Lewis 1980; Serow et al. 1984).

The proportional change in PPH since the most recent census (D_t) can be further adjusted to account for changes in the local mix of housing units. This can be important because single-family, multifamily, and mobile-home units often have considerably different values of PPH. For the United States in 1984, PPH was estimated as 2.94 for single-family units, 2.13 for multifamily units, and 2.48 for mobile homes (U.S. Bureau of the Census 1984). For many cities and counties these differences were even larger. Changes in the mix of housing units can therefore provide useful information on postcensal changes in PPH for many local areas. A technique for quantifying these changes can be found in Smith and Lewis (1980, pp. 328–329).

When households are estimated by type of unit, PPH can be estimated separately for each type. These estimates can be based on the national or regional changes in PPH measured by the Current Population Survey and can be adjusted upward or downward, depending on the value of PPH found in the most recent census for each type of housing unit. Housing data by type of unit can ordinarily be obtained from building permit or certificate of occupancy records and occasionally from utility company records (e.g., Houston Chamber of Commerce 1976; Tessmer 1976).

Estimates of PPH can also be based on data collected in special censuses or sample surveys. Special censuses are widely used by the State of Washington (Lowe et al. 1977). Postcensal changes in PPH are computed for places taking special censuses and are then used in making estimates of PPH for other places with similar characteristics. This technique has been successful in Washington, but it requires a large-scale, continuous program of special censuses. Such programs do not exist in most states. Sample surveys can be used to estimate PPH, but to provide accurate estimates, samples must be carefully drawn and quite large. The cost of such surveys generally prohibits their use for estimates of PPH.

Several researchers have used regression analysis to relate changes in PPH to changes in variables such as births, school enrollment, single-family units as proportions of total housing stock, and exemptions per income tax return (e.g., Comprehensive Planning Organization of the San Diego Region 1974; Voss and Krebs 1979). Current data on these symptomatic indicators of PPH can then be used to make current estimates of PPH. Although research along these lines appears promising, relatively little of this type of analysis has been performed to date, and to my knowledge no evaluations of the resulting estimation errors have been published.

Households and PPH are the two primary components of the HU method. Which can be estimated more accurately? The evidence seems to indicate that PPH can generally be estimated more accurately than the number of households. A study of county estimates in Florida reported an average error of 3.7% for estimates of PPH, compared with an average error of 7.2% for estimates of households (Smith and Lewis 1983). A study of city estimates in Oregon reported an average error of 6.3% for estimates of PPH, compared with 9.1% for estimates of households (Center for Population Research and Census 1984). A study of city estimates in New Jersey reported an average error of 4.4% for estimates of PPH and 6.1% for estimates of households (New Jersey Department of Labor 1984). A study of 47 large cities in the United States found that errors in estimates of households contributed more to total error than did errors in estimates of PPH (Starsinic and Zitter 1968).

All of these studies found larger errors for estimates of households than for estimates of PPH, but the reasons are not yet clear. One possible explanation is that PPH follows a steadier secular trend than the number of households, which can move substantially upward or downward in a short period of time. A second possible explanation is that the data used to estimate PPH may be more reliable than the data used to estimate households. A third possible explanation is that the number of households has changed more rapidly than PPH in recent years, thereby creating a greater potential for errors in estimates of households. Further research on this issue is needed.

Group Quarters Population

The number of persons living in group quarters (e.g., college dormitories, military barracks, prisons) is the last of the three components of the HU method. When large group quarters facilities are present, direct counts of the resident population are usually available from the administrators of the facilities. When an area has no large group quarters facilities, it is usually reasonable to assume that no change in group quarters population has occurred since the most recent census or that the group quarters population is growing at the same rate as population in households. Although errors for estimates of group quarters population can be quite large (e.g., Lowe et al. 1984; New Jersey Department of Labor 1984), group quarters population usually accounts for such a small proportion of total population that the estimate of group quarters population has very little effect on the overall population estimate. In a few places, of course, the estimate of group quarters population can have a major impact on the total population estimate (e.g., a small town with a large prison or college).

3. APPLICATIONS OF THE HOUSING UNIT METHOD

Table 1 summarizes the findings of a 1983 survey conducted by the Census Bureau, regarding the data and techniques used for making HU population estimates (U.S. Bureau of the Census 1983a). In this survey, questionnaires were sent to 301 state and local agencies identified in an earlier survey as preparing substate population estimates (U.S. Bureau of the Census 1978). One hundred sixteen agencies responded, of which 76 used some form of the HU method.

It is clear from Table 1 that a wide variety of data and techniques are currently used for HU population estimates. This section briefly describes the data and techniques used by agencies in Florida, New Jersey, Washington, and California. All four of these agencies are members of the Federal-State Cooperative Program for Population Estimates (FSCP), and their estimates carry official status. These examples represent only a few of the many applications of the HU method in the United States; however, they cover the most commonly used types of data and techniques and reflect the tremendous diversity found in current applications of the HU method.

Table 1. Data and Techniques Used by Agencies Producing Housing Unit Population Estimates

Components of HU Method	No. of Agencies
Housing Units or Households	
Building permits	60
Residential electric customers	6
Building permits and electric customers	4
Certificates of occupancy	4
Aerial photographs	2
Total	76
Persons per Household	
Most recent decennial census	51
Census, updated using surveys or special censuses	12
Census, updated using regression analysis	2
Census, updated using other variables	6
Extrapolated trends	5
Total	76
Occupancy Rates	
Most recent decennial census	52
Census, updated using surveys or special censuses	4
Ratio of electric customers to building permits	11
R. L. Polk vacancy survey	9
Total	76
Group Quarters	
Most recent decennial census	56
Census, updated using surveys or special censuses	18
Census, updated using administrative records	2
Total	76

Source: U.S. Bureau of the Census (1983a).

Florida

The Bureau of Economic and Business Research at the University of Florida prepares city and county population estimates through a contractual agreement with the State of Florida's Office of Planning and Budgeting. Two independent estimates of households are made, one using active residential electric customers (REC's) and the other using building permits (BP's). The REC household estimate uses the ratio technique described in Equation (5), and the BP household estimate divides housing units into single-family, multifamily, and mobile-home units, as described in Equation (3). Electric customer data are adjusted to account for the number of units served by master meters. Adjustments are also made for any annexations that may have occurred since the most recent census. Occupancy rates from the most recent census are used for the BP household estimates. The REC estimate is generally used as the final household estimate. When there appear to be problems with the REC data, the final household estimate is based on the BP estimate or an average of the REC and BP estimates.

Estimates of PPH are based on the level of PPH found in the most recent census, the national trend in PPH since that census (as measured by the Current Population Survey), and the local change in the mix of housing units. For BP household estimates, PPH is estimated separately for single-family, multifamily, and mobile-home units. For REC household estimates, PPH estimates are based on a formula that combines data from the most recent census, national trends since that census, and the change in local housing mix (Smith and Lewis 1980, pp. 328–329). The estimate of population in large group quarters such as college dormitories, military barracks, prisons, and state hospitals is based on direct counts by the administrators of those facilities. The population in other group quarters facilities is assumed to remain the same proportion of total population as it was in the most recent census. More detailed information on the techniques used in Florida and the accuracy of the estimates can be found in Smith and Lewis (1980, 1983) and Smith and Mandell (1984).

New Jersey

The Office of Demographic and Economic Analysis in the New Jersey Department of Labor uses the HU method for estimating the population of the state's municipalities; for state and county estimates, other methods are employed (New Jersey Department of Labor 1984). Housing units are estimated by using BP and demolition data to update the housing count from the most recent census, as shown in Equation (2). A six-month lag is used for permits involving fewer than 50 units, and 98% of permits are assumed to result in completed units. For permits involving 50 or more units, direct monitoring of construction progress indicates the date of completion of the units. Since mobile homes do not require building permits in New Jersey, annual mail surveys are conducted to measure changes in all known mobile home parks. Occupancy rates are based on those existing at the time of the most recent census and are adjusted upward or downward by the same proportion that occupancy rates for the northeast region of the United States have changed, according to the annual Current Housing Survey. Households are then estimated by applying these occupancy rates to the estimates of current housing units.

Estimates of PPH are based on the most recent census and are assumed to have changed since that census at the same rate as the PPH of the northeast region of the United States, as measured by the Current Population Survey. The population in large group quarters institutions (college dormitories, military barracks, prisons, long-term-care hospitals) is determined by direct contact with those institutions. For all other group quarters populations, the numbers are assumed to remain the same as they were in the most recent census.

Washington

The Population Studies Division of Washington's Office of Financial Management uses the HU method for municipal population estimates (Lowe et al. 1977, 1984). Housing units are estimated by using annual city reports on building permits and demolitions, by type of unit, as shown in Equation (3). This estimate is adjusted for reported conversions and annexations. For the first few years after a census, occupancy rates from that census are used as estimates of current occupancy rates. After several years have passed, occupancy rates are based on field surveys. Two alternate techniques are used for estimating PPH, depending on data availability. One technique is to extrapolate the PPH trend between the two most recent censuses, as in Equation (7). The other technique is to use recent PPH trends in "analogous" cities, or cities with similar characteristics that have had a special census in the recent past. Group quarters population estimates are based on information submitted by each city.

A unique feature of Washington's population program is its active special census program. Between 1970 and 1980, all but 53 of the state's 265 cities had at least one special census (Lowe et al. 1984, p. 2). The data collected in these censuses were used not only for estimates of the cities directly covered, but also to provide information regarding recent population trends for use in estimates of cities not covered by a special census. A major advantage of the HU method over other estimation methods is that it can incorporate such information directly into its estimating procedures.

California

The Population Research Unit in California's Department of Finance produces population estimates for cities and counties in California (California Department of Finance 1984). The HU method is used for estimates of cities and the unincorporated portion of each county; these subcounty estimates are then controlled to county estimates derived from other estimation methodologies. Building permits and certificates of occupancy are used to estimate the total number of housing units, by type, and residential electric customers are used to estimate the number of occupied housing units. The change in residential electric customers (adjusted for master meters, nonhousing uses, and annexations) is used as a measure of the change in occupied housing units, as in Equation (4). The number of occupied units is divided by the total number of units to give an occupancy rate, and this rate is used to evaluate the reliability of the building-permit, certificate-of-occupancy, and electric-customer data.

Estimates of PPH are based on trend analysis. The trend in PPH between the two most recent censuses is linearly extrapolated to the date of the current estimate, as in Equation (7). The extrapolated PPH is then adjusted upward or downward according to the analyst's evaluation of any factors that might have caused deviations from this trend, such as changes in housing mix, racial or ethnic composition, school enrollment, or birth rates. For larger cities, PPH estimates are made separately by type of housing unit. Estimates of group quarters population are based on counts taken from records of each group quarters facility.

4. EMPIRICAL EVIDENCE

As with any population estimation method, the usefulness of the HU method ultimately depends on the accuracy of its estimates. For a number of years many demographers perceived the HU method to be inaccurate, to have an upward bias, and to be subject to severe data limitations (e.g., Starsinic and Zitter 1968; Morrison 1971). In recent years the validity of this perception has been challenged by a growing number of demographers (e.g., Lowe et al. 1977; Smith and Lewis 1980; Gates 1981; Smith and Mandell 1984). We turn now to some tests of the accuracy of the HU method.

The HU method is used primarily for population estimates at the subcounty level. Florida is the only state in the FSCP in which the HU method is used for state and county estimates, as well as for city estimates. Table 2 reports on the performance of the HU population estimates for the 67 counties in Florida. Also shown is the performance of the Census Bureau's estimates, which are averages of the estimates from the Component II, ratio correlation, and administrative records methods. The errors summarized in Table 2 are the percent differences between 1980 estimates and 1980 census counts. These differences are called errors of the estimates, although they might have been caused by enumeration error as well as estimation error.

Table 2. Accuracy of Housing Unit and Census Bureau Population Estimates for Counties: Florida 1980

Size in 1970	No. of Areas	Mean Absolute % Error	Mean Algebraic % Error	% Error: 5% or Less	% Error: 10% or More
		Housing Unit Estimates			
<15,000	25	5.6	−1.1	52.0	16.0
15,000–49,999	18	7.2	−5.7	33.0	27.8
50,000–99,999	9	4.7	−4.0	55.6	0.0
100,000+	15	3.1	−1.8	80.0	0.0
Total	67	5.4	−2.9	53.7	10.4
Weighted average*		3.9	−2.7		
		Census Bureau Estimates			
<15,000	25	4.8	−3.1	56.0	8.0
15,000–49,999	18	6.8	−6.8	38.9	16.7
50,000–99,999	9	6.9	−6.9	33.3	22.2
100,000+	15	5.4	−5.4	33.3	6.7
Total	67	5.7	−5.1	43.3	11.9
Weighted average*		5.6	−5.6		

* Weighted by population size.
Source: Smith and Mandell (1984).

Table 2 shows mean absolute percentage errors, or the average when the sign of the error is excluded. This provides a measure of the precision of each method. It also shows mean algebraic percentage errors, or the average when the sign of the error is included. This provides a measure of the bias of each method. A mean algebraic error of zero indicates a lack of bias, whereas a positive or negative error indicates a tendency to overestimate or underestimate. Finally, Table 2 shows the proportion of errors that were less than 5% and the proportion that were 10% or more.

The HU estimates performed better than the Census Bureau estimates on all tests of estimation accuracy. The HU estimates were more precise, with an overall mean absolute error of 5.4%, compared with 5.7% for the Census Bureau estimates. The mean absolute percentage error weighted by population size was only 3.9% for the HU estimates, compared with 5.6% for the Census Bureau estimates, reflecting the relatively greater precision of the HU estimates for large counties. The HU estimates had less downward bias, with a mean algebraic error of −2.9%, compared with −5.1% for the Census Bureau estimates. The HU estimates also had a more concentrated distribution of errors, with a higher proportion of small errors and a lower proportion of large errors than the Census Bureau estimates. At the state level, the −2.7% error for the HU estimate was less than half as large as the −5.6% error for the Census Bureau estimate.

Census undercount, and particularly the change in undercount between 1970 and 1980, could affect the empirical results shown in this article. Adjustments that try to deal with this problem have been suggested (e.g., National Research Council 1980, pp. 232–236), but the usefulness of such adjustments for cities and counties is questionable because estimates of undercount for individual cities and counties are not available. Since the degree of undercount varies a great deal from one place to another, the application of a constant (or artificially varying) undercount adjustment factor to all cities and counties is not likely to provide useful information. In addition, estimates of the 1980 undercount for states and the nation are still subject to considerable disagreement among demographers (e.g., Ericksen and Kadane 1985). Because of this uncertainty, no adjustments for undercount were made in the present analysis.

Most HU population estimates are made for subcounty areas. Tables 3–6 show estimation errors for the four states in the FSCP that use the HU method for subcounty estimates and for which comparable 1980 data are available. These tables show the mean absolute percent error, the mean absolute percent error weighted by population size, the proportion of positive errors, and the proportion of large errors (10% or more) for two sets of estimates. The HU estimates are those produced by the states of Florida, New Jersey, California, and Washington, using the techniques described before. The administrative records (AR) estimates are those produced for the same four states by the Census Bureau, using the AR method. The AR method is one in which birth and death statistics are used to estimate natural increase, and changes of address reported on federal income tax returns are used to estimate net migration. It is the primary method used by the Census Bureau to make subcounty population estimates. A complete description of the AR method can be found in U.S. Bureau of the Census (1985).

The data shown in Tables 3–6 were taken from tables provided by the Census Bureau (U.S. Bureau of the Census 1982). These data have not been published previously, but complete copies of the original tables are available from the Census Bureau's Population Division or from me, upon request. Tables 3–6 summarize the errors for the HU and AR estimates, with errors again defined as the percent differences between 1980 estimates and 1980 census counts. Subcounty areas are defined as all incorporated places and the unincorporated balances of counties.

Table 3. Accuracy of Housing Unit and Administrative Records Population Estimates for Subcounty Areas: Florida 1980

Size in 1980	No. of Areas	Average % Error: Unweighted	Average % Error: Weighted*	% Positive Errors	% Errors, 10% or More
		Housing Unit Estimates			
<100	13	74.4	76.5	46.2	100.0
100–499	46	32.4	29.5	50.0	76.1
500–999	49	18.0	18.1	49.0	57.1
1,000–2,499	75	15.7	15.7	45.3	50.7
2,500–4,999	59	8.9	8.6	57.6	40.7
5,000–9,999	70	7.9	8.0	54.3	25.7
10,000–24,999	64	8.3	8.1	39.1	37.5
25,000–49,999	43	6.7	6.7	41.9	18.6
50,000–99,999	20	6.7	6.5	40.0	25.0
100,000+	21	3.8	3.8	23.8	9.5
Total	460	14.4	5.6	46.7	42.4
		Administrative Records Estimates			
<100	13	91.5	83.4	38.5	92.3
100–499	46	29.5	26.8	52.2	63.0
500–999	49	15.3	14.9	59.2	51.0
1,000–2,499	75	15.1	16.2	52.0	46.7
2,500–4,999	59	11.1	10.7	55.9	42.4
5,000–9,999	70	10.4	10.7	51.4	38.6
10,000–24,999	64	9.4	9.5	37.5	39.1
25,000–49,999	43	8.8	8.8	30.2	37.2
50,000–99,999	20	10.7	10.9	15.0	55.0
100,000+	21	9.8	9.1	4.8	47.6
Total	460	15.7	9.6	45.0	46.7

* Weighted by population size.
Source: U.S. Bureau of the Census (1982).

Table 4. Accuracy of Housing Unit and Administrative Records Population Estimates for Subcounty Areas: New Jersey 1980

Size in 1980	No. of Areas	Average % Error: Unweighted	Average % Error: Weighted*	% Positive Errors	% Errors, 10% or More
		Housing Unit Estimates			
<100	4	15.1	10.4	75.0	50.0
100–499	8	43.4	33.8	100.0	75.0
500–999	22	9.3	8.7	54.5	27.3
1,000–2,499	80	9.9	9.5	56.3	33.7
2,500–4,999	111	6.9	6.9	49.5	20.7
5,000–9,999	131	5.8	5.6	48.1	17.6
10,000–24,999	144	4.5	4.6	50.7	13.9
25,000–49,999	43	3.5	3.5	48.8	4.7
50,000–99,999	18	3.9	3.8	50.0	11.1
100,000+	4	3.7	4.4	25.0	0.0
Total	565	6.8	4.6	51.3	19.6
		Administrative Records Estimates			
<100	4	38.4	37.7	50.0	100.0
100–499	8	37.9	25.3	87.5	50.0
500–999	22	10.7	10.4	68.2	45.5
1,000–2,499	80	10.4	10.4	66.2	42.5
2,500–4,999	111	7.4	7.4	52.3	22.5
5,000–9,999	131	6.2	6.0	57.3	17.6
10,000–24,999	144	4.3	4.3	56.3	10.4
25,000–49,999	43	4.0	3.9	48.8	9.3
50,000–99,999	18	4.8	4.6	44.4	22.2
100,000+	4	5.6	6.3	25.0	0.0
Total	565	7.2	5.0	56.8	21.8

* Weighted by population size.
Source: U.S. Bureau of the Census (1982).

Table 3 summarizes the errors for Florida. The average error for all subcounty areas was 14.4% for the HU estimates and 15.7% for the AR estimates. The AR estimates were generally slightly more accurate for small places, and the HU estimates were considerably more accurate for large places. As a result, the weighted error for all places was only 5.6% for the HU estimates, compared with 9.6% for the AR estimates. The HU estimates also had fewer large errors than the AR estimates, and they had a more nearly even split of positive and negative errors.

Table 4 shows the results for New Jersey. The HU estimates had a smaller unweighted error (6.8% compared with 7.2%), a smaller weighted error (4.6% compared with 5.0%), fewer large errors, and a more nearly even split of positive and negative errors than the AR estimates. The differences between the HU and AR errors were generally quite small in New Jersey.

The differences between HU and AR errors were much larger in Washington. As seen in Table 5, both weighted and unweighted errors were only about half as large for the HU estimates as for the AR estimates. The overall unweighted errors were 5.8% for the HU estimates and 11.7% for the AR estimates; the overall weighted errors were 4.3% for the HU estimates and 7.8% for the AR estimates. The HU estimates had less than half as many large errors as the AR estimates, and they had considerably closer to an even split of positive and negative errors.

The HU estimates were also more accurate than the AR estimates in California. Table 6 shows an average error of 5.3%

Table 5. Accuracy of Housing Unit and Administrative Records Population Estimates for Subcounty Areas: Washington 1980

Size in 1980	No. of Areas	Average % Error: Unweighted	Average % Error: Weighted*	% Positive Errors	% Errors, 10% or More
		Housing Unit Estimates			
<100	5	14.6	6.5	20.0	40.0
100–499	57	7.1	6.7	68.4	28.1
500–999	46	5.6	5.6	56.5	17.4
1,000–2,499	67	6.8	6.8	52.2	22.4
2,500–4,999	40	3.8	3.7	52.5	5.0
5,000–9,999	32	5.6	5.7	43.8	15.6
10,000–24,999	29	4.5	4.5	34.5	3.4
25,000–49,999	19	4.1	4.1	42.1	5.3
50,000–99,999	4	5.1	5.4	50.0	0.0
100,000+	9	4.5	3.9	22.2	11.1
Total	308	5.8	4.3	51.3	16.6
		Administrative Records Estimates			
<100	5	20.5	13.6	40.0	80.0
100–499	57	13.7	12.2	66.7	52.6
500–999	46	15.5	15.4	73.9	39.1
1,000–2,499	67	10.2	9.8	65.7	32.8
2,500–4,999	40	13.5	12.3	65.0	27.5
5,000–9,999	32	7.8	8.1	50.0	31.3
10,000–24,999	29	7.1	7.3	48.3	24.1
25,000–49,999	19	10.9	10.7	52.6	26.3
50,000–99,999	4	9.1	9.3	50.0	25.0
100,000+	9	8.2	6.3	22.2	44.4
Total	308	11.7	7.8	61.0	36.4

* Weighted by population size.
Source: U.S. Bureau of the Census (1982).

for the HU estimates, compared with 7.0% for the AR estimates. The weighted error was 4.1% for the HU estimates and 4.6% for the AR estimates. The split between positive and negative errors was virtually identical for the two methods, but the HU estimates had considerably fewer errors of 10% or more.

In summary, the empirical analysis shows the HU population estimates in Florida, New Jersey, California, and Washington to have been more accurate than competing estimates, according to three criteria. The HU estimates were more precise, having smaller mean absolute percentage errors (both unweighted and weighted by population size). The HU estimates were less biased, with a more nearly even split of overestimates and underestimates than the other methods. (There was no evidence of a positive bias, as two states had substantially more negative than positive errors and two had slightly more positive than negative errors). Finally, the HU estimates had fewer large errors than the other estimates. Although the differences were often quite small, the superior performance of the HU method was seen in every test of estimation accuracy and, perhaps more important, in every set of data. The old characterization of the HU method as intrinsically inaccurate and biased must finally be laid to rest; there is simply too much evidence to the contrary.

Table 6. Accuracy of Housing Unit and Administrative Records Population Estimates for Subcounty Areas: California 1980

Size in 1980	No. of Areas	Average % Error: Unweighted	Average % Error: Weighted*	% Positive Errors	% Errors, 10% or More
		Housing Unit Estimates			
<100	1	155.6	155.6	100.0	100.0
100–499	6	17.1	15.6	83.3	66.7
500–999	10	5.9	6.0	60.0	20.0
1,000–2,499	27	7.1	6.4	51.9	25.9
2,500–4,999	56	6.5	6.8	46.4	25.0
5,000–9,999	69	5.0	4.8	39.1	11.6
10,000–24,999	107	5.1	4.8	43.9	11.2
25,000–49,999	89	4.0	4.0	38.2	6.7
50,000–99,999	68	3.7	3.7	27.9	5.9
100,000+	41	3.9	4.0	14.6	0.0
Total	474	5.3	4.1	39.0	12.2
		Administrative Records Estimates			
<100	1	198.9	198.9	100.0	100.0
100–499	6	19.6	19.2	100.0	83.3
500–999	10	10.3	10.7	50.0	40.0
1,000–2,499	27	11.4	11.5	66.7	44.4
2,500–4,999	56	8.9	9.0	41.1	33.9
5,000–9,999	69	7.3	7.0	44.9	23.2
10,000–24,999	107	6.0	5.8	36.4	15.0
25,000–49,999	89	5.1	5.2	32.6	13.5
50,000–99,999	68	4.7	4.7	33.8	2.9
100,000+	41	4.8	4.0	22.0	9.8
Total	474	7.0	4.6	38.8	19.2

* Weighted by population size.
Source: U.S. Bureau of the Census (1982).

A comparison of Tables 3–6 shows levels of error to have varied considerably from state to state. These differences were caused by differences among states in rates of growth, the distribution of cities by size of place, changes in seasonal population, and other factors that affect estimation errors. It is interesting to note, however, that the relationships between HU errors and AR errors were similar from state to state. In states where the AR estimates had relatively large mean absolute errors (e.g., Florida), the HU estimates also had relatively large errors. In states where the AR estimates had a relatively high proportion of positive errors (e.g., New Jersey), the HU estimates also had more positive than negative errors. In states where the AR estimates had a relatively small proportion of large errors (e.g., California), the HU estimates also had a relatively small proportion of large errors. Since the AR method is applied uniformly in all states, it provides a benchmark against which the HU estimates can be compared. It is therefore noteworthy that the performance of the HU method relative to the AR method was quite similar in Florida, New Jersey, and California, even though the data and techniques used in applying the HU method differed considerably from state to state.

The only exception was Washington, where the HU estimates had considerably smaller errors than the AR estimates. The relatively greater accuracy of the HU estimates in Washington was most likely the result of the large number of special censuses taken in that state during the 1970s. Eighty percent of Washington's cities had at least one special census between 1970 and 1980, making the base for the HU estimates much more current than is ordinarily the case, and thereby lowering the potential for estimation error.

5. CONCLUSION

The HU method is a robust, comprehensive, and extremely flexible form of population estimation. It has a number of characteristics that make it very useful for small-area analysis. It is conceptually simple and can be easily explained to and understood by nondemographers (more than a minor advantage when population estimates must be described and defended in public forums). It is not confined to a single technique or type of data; rather, it can utilize a number of different techniques and data sources, including those that may be applicable in one area but not another. It can be applied at virtually any level of geography, from states to census tracts, block groups or zip code areas. This is a tremendous advantage over other commonly used estimation procedures because they generally cannot be used below the county level: The data required by regression and component methods are seldom available for subcounty areas, and the income tax data used in the AR method cannot be used by anyone other than the Census Bureau. Most important, the HU method can produce accurate population estimates.

Yet the HU method is more a general approach to population estimation than a specific set of estimation techniques. This is its greatest strength but also its greatest weakness. It is a strength because the HU method can be adapted to use unique data sources and to fit any geographic area, and when applied carefully it can produce accurate estimates. But the numerous techniques and data sources that can be used for HU population estimates can lead to abuses, with the method being applied simplistically, using poor data and assumptions and producing inaccurate estimates. Therefore judgments regarding the reliability of a specific set of HU population estimates must always be based on the validity of the data and assumptions used in that particular application of the method, not on an assessment of the theoretical and empirical validity of the HU method in general.

Accurate HU population estimates require a major commitment of resources. A great deal of effort must be made to ensure that data series are consistent over time, that reporting errors have not occurred, that geographic boundaries have not changed, and that unique local features have been noted. Without this effort, accurate estimates on a broad scale cannot be made. The states of Florida, New Jersey, Washington, and California use quite different techniques for applying the HU method, yet each state obtains very good results because each is able to provide the time, expertise, and money needed to produce high-quality population estimates. The HU method is a conceptually simple form of population estimation, but it will provide accurate estimates only if sufficient resources are devoted to its application.

The HU method is not without its problems, of course. Estimates for small places often have very large errors. The quality and consistency of building permit and utility customer data are not always good. Changes in PPH trends sometimes go unnoticed. Changes in vacancy rates and seasonal population are difficult to monitor. These are only some of the areas in which problems remain. Many improvements in the HU method have been made in recent years, and more will be made in the future. The HU method is a constantly evolving approach to population estimation and has not yet reached the limits of its development. I am confident that further research and testing will uncover new sources of data and establish new techniques that will increase its accuracy and widen its applicability, making the HU method an ever more useful approach to local population estimation.

[Received December 1984. Revised October 1985.]

REFERENCES

Bureau of Economic and Business Research (1983), unpublished tables, University of Florida.

California Department of Finance (1984), *Housing Unit Method Manual*, Sacramento, CA: Author (Population Research Unit).

Center for Population Research and Census (1984), unpublished tables, Portland State University, School of Urban and Public Affairs.

Comprehensive Planning Organization of the San Diego Region (1974), *A Model for Estimating Household Size in the San Diego Region*, San Diego, CA: Author.

Ericksen, Eugene, and Kadane, Joseph (1985), "Estimating the Population in a Census Year: 1980 and Beyond," *Journal of the American Statistical Association*, 80, 98–109.

Findley, Sally (1979), "Nonlinear Estimation of Household Size: The Minnesota Housing Unit Method," Technical Memorandum 79-1, Minnesota State Planning Agency, Office of State Demographer.

Gates, Albert (1981), "Estimating Population From Housing Units: A Preliminary Evaluation Using 1980 Census Data," unpublished paper presented at the annual meeting of the Southern Regional Demographic Group.

Hodges, Kenneth, and Healy, Mary Kay (1984), "A Micro Application of a Modified Housing Unit Model for Tract Level Population and Housing Estimates," unpublished paper presented at the annual meeting of the Population Association of America.

Houston Chamber of Commerce (1976), *Population, Households and Dwelling Units in Harris County Census Tracts*, Houston: Author (Research Division).

Lowe, Theresa, Myers, William, and Weisser, Lawrence (1984), "A Special Consideration in Improving Housing Unit Estimates: The Interaction Effect," unpublished paper presented at the annual meeting of the Population Association of America.

Lowe, Theresa, Pittenger, Donald, and Walker, John (1977), "Making the Housing Unit Method Work: A Progress Report," unpublished paper presented at the annual meeting of the Population Association of America.

Mindlin, Albert, Ahuja, Gangu, and Kunen, Marcia (1977), "A Model for Current Estimates of Housing Units and Components of Inventory Change, Utilizing Local Records, 1970 Census and Census Annual Housing Survey, 1974," unpublished paper presented at Federal Statistics Users Conference on State and Local Area Information for Socioeconomic Analysis.

Morrison, Peter (1971), *Demographic Information for Cities: A Manual for Estimating and Projecting Local Population Characteristics*, Report R-618-HUD, Santa Monica, CA: Rand Corporation.

National Research Council (1980), *Estimating Population and Income for Small Areas*, Washington, DC: National Academy Press.

New Jersey Department of Labor (1984), *An Evaluation of Population Estimating Techniques in New Jersey*, Trenton, NJ: Author (Office of Demographic and Economic Analysis).

Serow, William, Eberstein, Isaac, Mayberry, Linda, and Rives, Norfleet (1984), "Can Simple Techniques Produce Useful Small-Area Population Estimates?" unpublished paper presented at the North American meeting of the Regional Science Association.

Siskind, David (1980), "Housing Construction Data Vital," *Data User News*, 15, No. 2, 1–3, 10–14.

Smith, Stanley, and Lewis, Bart (1980), "Some New Techniques for Applying the Housing Unit Method of Local Population Estimation," *Demography*, 17, 323–339.

——— (1983), "Some New Techniques for Applying the Housing Unit Method of Local Population Estimation: Further Evidence," *Demography*, 20, 407–413.

Smith, Stanley, and Mandell, Marylou (1984), "A Comparison of Population Estimation Methods: Housing Unit Versus Component II, Ratio Correlation and Administrative Records," *Journal of the American Statistical Association*, 79, 282–289.

Starsinic, Donald, and Zitter, Meyer (1968), "Accuracy of the Housing Unit Method in Preparing Population Estimates for Cities," *Demography*, 5, 475–484.

Tessmer, Raymond (1976), "Estimation of Housing and Population Data From Electric Meter Records," *Review of Public Data Use*, 4, 31–36.

U.S. Bureau of the Census (1978), *Current Population Reports*, Ser. P-25, No. 723, Washington, DC: Author.

——— (1982), "Local Estimates for Subcounty Areas," unpublished memorandum, Washington, DC: Author.

——— (1983a), "Survey of Local Agencies Using the Housing Unit Method," unpublished memorandum, Washington, DC: Author.

——— (1983b), *Current Housing Reports*, Ser. H-111-82-5, Washington, DC: Author.

——— (1983c), *Current Population Reports*, Ser. P-20, No. 382, Washington, DC: Author.

——— (1984), "Current Population Survey," unpublished data, Washington, DC: Author.

——— (1985), *Current Population Reports*, Ser. P-25, No. 963, Washington, DC: Author.

Voss, Paul, and Krebs, Henry (1979), *The Use of Federal Revenue Data for Improving Current Estimates of Average Household Size for Minor Civil Divisions: An Evaluation*, Technical Ser. 70-5, University of Wisconsin, Madison, Applied Population Laboratory.

Walker, P. A., and Davis, J. R. (1981), "Reconciling Dwelling Stock Estimates With Census Data," *Review of Public Data Use*, 9, 167–174.