# Chapter 9
# Population Change and Its Measurement

**Abstract** Population change is a major area of interest in applied demography, and this chapter considers the key techniques used in the production of estimates, projections and forecasts. The various approaches to generating "synthetic data" are considered along with the pros and cons of the available techniques. In addition to basic statistical techniques more complex methods of producing estimates and projections are considered.

## 9.1 Introduction

Demographers pay considerable attention to population change since this phenomenon has implications for population size, distribution and composition. A population's characteristics at any point in time represent a static "snapshot" of that population, and it is the changes that occur in a population over time that represent the dynamic aspects. Population change is an inevitable aspect of social existence. Even the most stable traditional society will undergo change as a result of demographic processes, albeit sometimes at an imperceptible rate. Even in the absence of migration, differential birth rates or deaths rates for subgroups in society will result in compositional change. This is occurring in the United States today, for example, as the white population displays lower birth rates than various minority populations, leading to a restructuring of the racial and ethnic composition of the country's population.

While the measurement of population change is a critical activity of demographers, there are often situations in which adequate information is not available for this purpose. There are situations when a current population count is needed but not available due to the fact that no actual or estimated data can be obtained for the geography in question. There are other occasions in which information on population size and characteristics is desired for a past time period for which data are not available or for a future time period for which data are obviously not available. In these situations, demographers rely on population estimates, projections and, to a lesser extent, forecasts. Using well-established techniques, data on population size

 
R. K. Thomas, *Concepts, Methods and Practical Applications in Applied Demography*, https://doi.org/10.1007/978-3-319-65439-3_9

and in some instances population characteristics (that is, synthetic data) are generated for past, present and future time periods. (Note that the range of techniques available for generating estimates, projections and forecasts cannot be fully covered in one chapter. The additional resources cited at the end of this chapter should be helpful in providing guidance to the wide range of techniques available for generating these statistics.)

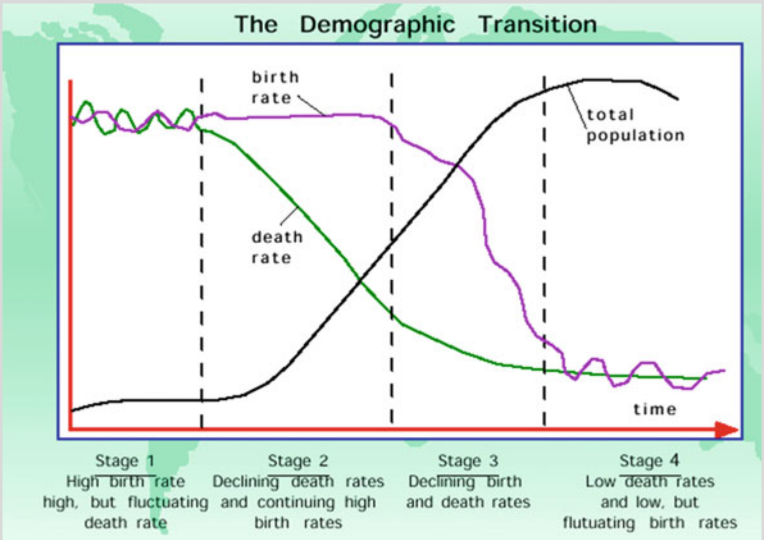
*There are often situations in which the desired data are not available and demographers must generate "synthetic data" in the form of estimates, projections and forecasts.*

Demographers often rely on government sources of population data (see section on data sources below). The federal government (by virtue of the Census Bureau) is the major source of demographic data. However, the now limited data generated through the decennial census are not available for a year or often longer after collection and are quickly dated. Data from the American Community Survey are also not available for a year or more after collection. While the Census Bureau and state data agencies may calculate projections for future years they seldom provide data below the county level. For data at the sub-county level non-governmental sources may have to be accessed. For these reasons, applied demographers must acquire the skills necessary to produce estimates and projections.

Since the focus of this book is applied demography limited attention is paid to demographic theory. However, much of the research on population change has been informed by the work carried out by demographers related to the demographic transition. Exhibit 9.1 describes the key contribution demographers have made to theories of population change.

**Exhibit 9.1: The Demographic Transition**

Demographers describe the "demographic transition" (DT) as a process involving a population's transition from high birth and death rates to low birth and death rates as a society evolves from a pre-industrial society into an industrialized soceity. Demographic transition theory is based on an interpretation of demographic history developed by the American demographer Warren Thompson (1929) based on his examination of changes in birth and death rates in industrializing societies over the previous 200 years. This process is typically represented by the demographic transition model (DTM) illustrate below.




In Stage 1, for countries in the pre-industrial phase of development death rates and birth rates are high and roughly in balance. All human populations are believed to have exhibited this balance of births and deaths until shifts began occurring in Western Europe in the late 18th century. Because the two rates are approximately in balance, population growth is typically very slow in Stage 1. In Stage 2 death rates drop rapidly as improvements in food supply and sanitation increase life expectancy and reduce the impact of disease. Without a corresponding fall in birth rates this produces an imbalance in vital events, and the countries in this stage experience a large and unprecedented increase in population.

In Stage 3, birth rates fall due to access to contraception, increases in wages, urbanization, a reduction in subsistence agriculture, and other social changes. Population growth begins to level off as a result. The decline in birth rates in developed countries started in the late 19th century in northern Europe. During Stage 4 both birth rates and death rates fall to unprecedented low levels. Birth rates, in fact, may drop to well below replacement level as has happened in countries like Germany, Italy, and Japan. Death rates may remain consistently low or increase slightly due to increases in lifestyle diseases and an aging population in developed countries.

By the late 20th century, birth rates and death rates in developed countries had leveled off at rates that resulted in little or no population growth. Most developed countries today are in Stage 3 or 4 of the model; the majority of developing countries have reached Stage 2 or Stage 3. Major exceptions to this process are some poor countries in sub-Saharan Africa and the Middle East which remain in Stage 1.

As with all models, this is an idealized picture of population change. The model is a generalization that applies to groups of countries and may not accurately describe each individual case. The extent to which it applies to less-developed societies today remains to be seen. Many countries such China, Brazil and Thailand have passed through the Demographic Transition Model very quickly due to rapid social and economic change. Some countries, particularly African countries, appear to be stalled in the second stage due to stagnant development and the effect of AIDS.

*Source* Thompson (1929).

Whether the demographer is interested in generating estimates, projections or forecasts, certain procedures should be followed. Assumptions should be made about the best approach to follow, and this may be dictated by a number of factors. Further, assumptions must be made concerning observed trends. If, for example, the population has been changing at a certain rate for several years assumptions should be made relative to the likelihood that it will continue to grow or decline at the same rate in the future. Finally, assumptions must be made concerning the quality of the data to which the analyst has access. If using census data the demographer can be fairly confident of the quality of the data (or at least know that it is recognized as the "gold standard"). If using data from some other source care must be taken to assure that the quality of the data is adequate.

## 9.2 Estimation Techniques

Population estimates are typically calculated when there is no actual data available. Most often demographers speak of current estimates (i.e., for the current time period or one near the current time period). However, estimates may be made for future or past years when existing data points are available for past time periods or future time periods if projections are already available.

*"Interpolation" and "extrapolation" are commonly used methods by demographers to generate estimates and projections.*

Population estimates can be either simple or complex. The simplest approach to estimating or projecting change is to use known data points to extrapolate or interpolate data. Obviously, the more data points one has access to, the more reliable the estimate or projection. Exhibit 9.2 discusses the interpolation and extrapolation processes that are employed in the generation of estimates and projections.

**Exhibit 9.2: Using Interpolation and Extrapolation Techniques**

Demographers use interpolation and extrapolation as methods for generating estimates and projections. Most estimates employ an interpolation approach when existing data points can be accessed. This method assumes that a population figure for an intermediate year will fall somewhere between the populations identified for the beginning and ending periods. For example, if one were interested in a mid-decade population estimate (e.g., 2005), the estimate could be interpolated from the figures for 2000 and 2010. Theoretically, the mid-decade estimate would represent the mid-way point between the two figures (or, in this case, the average of the two). Although the mid-year population could fall outside the range of the two data points, this is assumed to be very unlikely.

When interpolation is used assumptions must be made, of course, concerning the rate of change for that decade, with the most straightforward approach assuming that the rate of change is constant over the time period in question. However, if there is evidence that the rate of change is faster or slower for some period within the ten-year time interval, the assumptions must be modifired. An assumption of this type must be made whether the rate of change is calculated in terms of numerical change or percentage change.

When calculating projections (and forecasts) the extrapolation method is typically used when past and/or current data are available. The rationale behind extrapolation is that, once a trend has been established, it can be expected to continue into the future on a similar trajectory. This is a "leap of faith" of course in that many factors can serve to divert a trend that has been underway for some time. Yet, the assumption of a continued trajectory is often made and, for the most part, can be empirically demonstrated. Thus, if an analysis wanted to project the population for 2020 for a defined population, it would be possible to extrapolate from existing data points into the future. The analyst could determine the numerical change between 2000 and 2010 based on census figures and assume the same absolute or percentage change for 2020. With the technique the 2000–2010 trend is extrapolated into the future. Interpolation could also be used for generating a projection if projections of populations for future years have been generated. For example, if the 2010 population count for the U.S. is available and the Census Bureau has generated a projection for the U.S. population in 2030, interpolation could be used to yield a projection for 2020.

A number of techniques are available for this purpose some of which are considered "reality-based" estimates. These types of techniques tend to rely on "proxy" or "symptomatic" measures of population size and distribution. This approach utilizes data that is thought to be a representation of the population based on some logical correlate. For example, some fairly direct measures of the number of households within a defined area might be determined by the number of utility hookups, on the assumption that all occupied dwellings require electricity, gas and/or water. Of course, assumptions have to be made with regard to household size since the only information available is the number of occupied units that are hooked up to the utility system. A less direct method might involve the use of school enrolment data as a means of estimating population size. This method requires assumptions about the ratio of students to adults in a population and has to take into consideration private schools and home schooling. Data for proxy or symptomatic measures such as utility hookups and school enrolment are generally publicly available, providing an easily accessible source of proxy data.

*Reality-based estimates may use proxy or symptomatic data as a basis for generating population estimates in the absence of actual data.*

A reality-based method that is particularly useful in developing population estimates—assuming the requisite data are available—is the *housing-unit method*. This method has some similarities to the utility hookup estimates but is thought to provide a greater depth of understanding of the phenomenon under investigation. This approach involves starting with a known population—e.g., the "official" count from the most recent census—and employs an approach similar to the component method. Here, however, the "components" are housing units added to the community over a set period of time and housing units that are removed from the community over the same period. Thus, to the known number of housing units for Time 1 the analyst adds new home construction, new apartment construction, and newly established mobile homes between Time 1 and Time 2.

From the housing stock extant during Time 1 the analyst must subtract housing units (i.e., homes or apartments) that are demolished or otherwise taken out of stock and mobile homes that are eliminated. The required information on these activities is generally available from public records, although the availability, completeness and currency have to be considered on a case-by-case basis.

The other factor that must be addressed, of course, is the average number of occupants for each type of housing unit. This information is generally available from American Community Survey data for the target area and can be applied to each type of unit. Finally, adjustments have to be made for occupancy rates for the various types of housing units since unoccupied housing will not contribute individuals to the population total. The figures generated for each type of housing unit are then summed to yield a population estimate for Time 2. While this approach is not able to take the homeless and migrant workers into consideration, for a "normal" population its specificity in terms of housing type makes it a useful technique.

Another approach that is commonly used by demographers to generate population estimates and—less commonly—projections is the *ratio method*. This approach assumes that the share of the population for a geographical subunit represents a specified proportion of the total population, and that a constant ratio exists between the total population and the population for the sub-unit under study. Hence, past relationships between population growth in an area or community and that of its economic region or State are valuable guides for projecting the population of geographical sub-units.

For example, for the United States, it is assumed that the population of a particular state represents a certain proportion of the total population and, further, that this ratio remains constant over time. Thus, assuming that one has an accurate count for the highest level of geography (e.g., the United States), it is possible to estimate the population for each of the states based on its population's ratio to the whole. If New York state historically accounts for 10% of the nation's population, it can be assumed, then, that it will account for 10% of the newly determined national population. The same procedure could be followed for any sub-unit, with county populations being derived from the state population, census tract populations being derived from the county population and so forth.

## 9.3 Projection Techniques

Projections are utilized to generate population statistics for future years. The most parsimonious methods used for population projections are considered *constant change* methods of population extrapolation. These approaches assume that population growth follows natural laws and, therefore, can be expressed in mathematical or graphical form. Basically, the future population is forecast by examining past trends and projecting these trends into the future. The assumption is that the pattern observed for the past (e.g., increase, decrease) can be expected to continue into the future. This is typically a wholly mathematical exercise and does not consider the components that contribute to the observed change.

The data used for generating projections utilize historic data from decennial census reports and/or available local or State reports. Two data points (Time 1 and Time 2) are sufficient for generating a trend line and extrapolating into the future. If more data points are available all the better, although the construction of the trend line may become more complicated. In using the plotted information for projection purposes, the analyst assumes that the condition implied by the straight line will continue into the future.

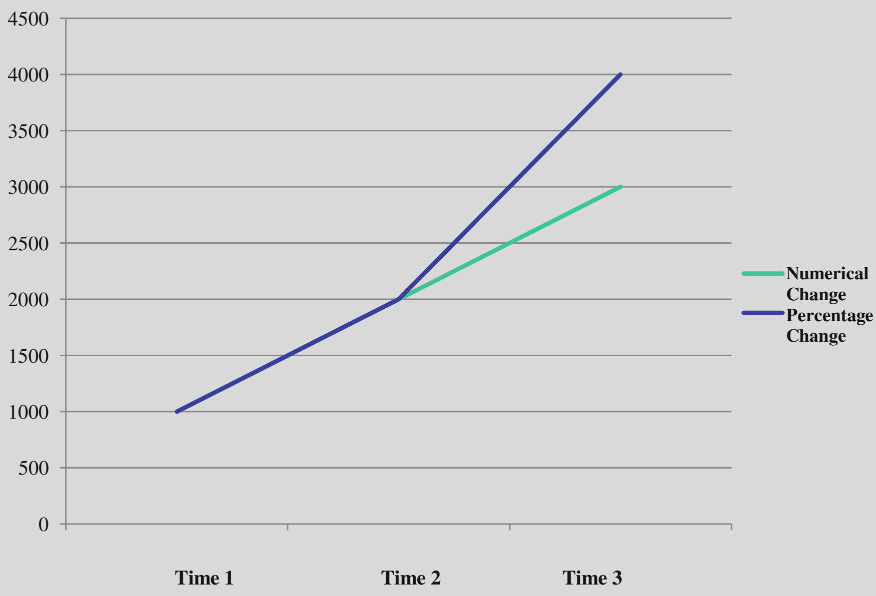
*In generating population projections demographers make assumptions about the extent to which observed historic trends can be expected to hold in the future.*

It is not necessary to be familiar with semi-log or other mathematical frameworks to generate straight-line projections, and analysts may opt to use a method based on a constant arithmetic population change or a constant proportional population change. For the former, historic data which plot as a straight line on arithmetic graph paper imply constant arithmetic change in population each year. This growth pattern implies that the population has changed by the same number of people each year. The data would appear as a straight line when plotted on arithmetic paper. If it has been found, for example, that over a ten-year period the average annual increase was 1000 residents for a defined geographical area, then this figure (1000 per year) would be extrapolated into the future.

Not only does the approach assume that there is a constant average year-to-year increase but that the increase observed over the historical period was also constant year to year. For a defined geography it is found, for example, that the population increased by 10,000 over a ten-year period—or an average of 1000 per year. It is possible, however, that most of the increase occurred during the first years of the decade but slowed during the later years. Or, it could have been that the population was relatively stagnant during the first few years of the decade, with rapid growth occurring within the last few years. While the constant change method does not require that such factors be taken into consideration, if there is evidence of inconsistent change over the study period, the projection generated may be misleading.

An alternative to the numerical approach is the constant percentage change method. If one analyzed the numerical change results it would be found that, since the base population each year has increased (or decreased) by a constant amount, the rate of change is different for each year resulting in a different pattern of growth —that is, curvilinear). When the same data are plotted on semi-log paper (with population on the log scale and time on the arithmetic scale), a straight-line plot results. In this situation, the numerical increase each year is greater than the year before, although the rate of increase is constant. Exhibit 9.3 illustrates the results generated by using the two different models (numerical and percentage).

**Exhibit 9.3: Two Projection Models**




The ratio method described above for use in generating estimates can also be used for projecting populations for sub-units. The population growth of a study area can be projected into the future by relating its growth to a larger area of which it is a part, such as a state, a region, or the nation. The basic procedure is to compute the ratio between the population of the study area and some larger area at the time of past censuses. This ratio may simply be between the study area and a larger area, or a series of interrelated ratios may be calculated between pairs of successively smaller geographical areas. Such a series, known as step-down ratios, might be between the study area and the State economic area, the State economic area and the whole State, the State and the region and, finally, the region and the Nation. This method requires the availability of a reliable projection for the larger area and comparable historic data for the subareas to be used should be examined before.

*The component method of calculating population change considers the three primary factors that influence population growth and decline—fertility, mortality and migration.*

One commonly used method for projections is the *component method*. There are three components to population change to consider: fertility, mortality and migration. Individuals are added to the population through the fertility process (births) and subtracted through mortality process (deaths). Individuals are added to a population through in-migration and subtracted through out-migration. Thus, the population at Time 2 is a result of adding births and in-migrants and subtracting deaths and out-migrants from the population at Time 1. Population change resulting from the addition of births and the subtraction of deaths is referred to as “natural increase” (or decrease as the case may be). In a closed society, these are the only factors that influence population change. Since there are virtually no closed societies, the role of migration must be factored into the equation. Exhibit 9.4 describes the calculation of projections using the component method. Exhibit 9.3 provides formulas for the calculation of population change using the component method.

**Exhibit 9.3: Calculating Population Change, Component Method**
The component method for calculating population change uses births, deaths and migration flows as the basis for generating synthetic data. The first formula illustrates the calculation of natural increase/decrease while the second formula introduces migration into the equation.

Natural Increase/Decrease

$$\text{Pop}_2 = \text{Pop}_1 + \text{Births} - \text{Deaths}$$

Example:

$$\text{Pop}_{2000} = \text{Pop}_{1990} + \text{Births and - Deaths}_{1990-2000}$$
$$\text{Pop}_{2000} = 10,000 + 6000 - 1000$$
$$\text{Pop}_{2000} = 15,000$$

Natural increase = 5000

Natural Increase/Decrease and Migration

$$\text{Pop}_2 = \text{Pop}_1 + \text{Births} - \text{Deaths} + \text{Migration}$$

Example:

$$\text{Pop}_{2000} = \text{Pop}_{1990} + \text{Births and} - \text{Deaths}_{1990-2000} + \text{In-migration and} - \text{Out-Migration}$$

$$\text{Pop}_2 = \text{Pop}_1 + \text{Births} - \text{Deaths} \pm \text{Migration}$$
$$\text{Pop}_{2000} = 10,000 + 6000 - 1000 + 3000 - 1000 = 17,000$$

Population Change = +7000

Another available projection technique involves the use of *cohort-change ratios* (CCRs). This technique (also referred to as the Hamilton-Perry Model) can be used to develop projections not only by age, but by age and sex, age and race, sex and race, and so on (Swanson & Tedrow, 2017). The major advantage of this method is that it has much smaller data requirements than the traditional cohort-component method. Instead of mortality, fertility, migration, and total population data, the Hamilton–Perry method simply requires data from the two most recent censuses. This method can be used to project population by age and sex using cohort-change ratios computed from census data or other data sets involving successive time periods. In its simplest form this approach involves cohort-to-cohort advances over time. For example, the number of persons in the 20–24 age cohort in Time 2 should be similar to the number in the 10–14 age cohort tens year previous (if one is using decennial census data). The same is true for any other age cohort except, as noted below, the very youngest and very oldest cohorts. Assumptions must be made, of course, related to the impact of immigration and mortality on the population under study.

Given the nature of the CCRs, 10–14 is the youngest age group for which projections can be made (if there are 10 years between censuses). To project the population aged 0–4 and 5–9 one can calculate the Child Woman Ratio (CWR) and incorporate it into the model. This does not require any data beyond what is available in the decennial census. Projections of the oldest open-ended age group differ slightly from the CCR projections and require that the three oldest cohorts be grouped for calculating the population in the oldest cohort.

The cohort-change ratio from time period to period should equal 1.00 or less in the absence of any disruptive event. A cohort-change ratio greater than 1.00 indicates that more increments (e.g., in-migrants) then decrements (e.g., deaths and out-migrants) occurred during the interval. Thus, for example, a fast-growing suburb would yield a higher ratio due to the fact that the numbers added to the population between censuses exceeded the numbers lost to death or out-migration.

One disadvantage of the cohort-change ratio method is that it can lead to unreasonably high projections in rapidly growing places and unreasonably low projections in places experiencing population losses. Geographic boundary changes are an issue as well. Since extrapolation methods of this type are based on population changes within a given area, it is essential to develop geographic boundaries that remain constant over time. For some sub-county areas, this presents a major challenge, however. Case Study 9.1 describes a demography-based technique for predicting the demand for health services.

## 9.4 Generating Forecasts

*Forecasts* represent a special—and an infrequently used—form of synthetic data. Given the variety of factors that could contribute to population change, forecasts may make sense in some cases. Econometric approaches to forecasting use equations that project utilization as a function of the interplay of independent variables based on multiple factors make more sense than forecasts based on a single factor. Theoretically, the more factors used in predicting future conditions, the more accurate the prediction will be.

**Case Study 9.1: Using Population Projections to Anticipate Health Services Demand**

Demographers involved in the planning of health services require access to data on disease incidence and prevalence, as well as data on the volume of health services consumed. However, there is no central repository of data on either the amount of morbidity within a population or the level of health services required to meet the needs of that population. Yet, this information is essential for the development of an informed health plan.

Health demographers do have some options in that the distribution of diseases in contemporary America exhibits a strong association with certain demographic characteristics. Unlike past acute conditions, today's chronic conditions are highly correlated with the demographic attributes of a population. Thus, if the demographer has access to key demographic data for a defined population—e.g., the age and sex distribution—and utilization rates for various types of services it is possible to estimate and project health services demand for that population.

A case in point might be the need to estimate the demand for various physician specialties. A hospital, for example, may be initiating a physician recruitment effort or a chain of primary care clinics might be considering establishing a site in a newly developed community. Assuming that the analyst has access to the age-sex breakdown for the target population it becomes possible to generate estimates and projections of the demand for various medical specialties among other factors.

Data are available from the National Center for Health Statistics that indicate physician utilization rates for each five-year cohort for males and females separately. It then becomes a simple matter of applying the age/sex-specific rates to each cohort to generate the anticipated number of cases. The estimates based of age and sex are typically adjusted for region of the country and, to the extent that additional attributes are available, they could be adjusted for race, income, insurance status or some other factor. Admittedly, these are modeled data but, in the absence of actual data, they represent the best possible estimate. Estimates and projections can be generated for any time period as long as the requisite inputs are available. The table below presents the anticipated number of visits for selected specialties for a specific metropolitan area in 2017.

Estimated Physician Visits for Selected Specialties, Metro Service Area, 2017

| | |
|---|---|
| Family Practice | 56,683 |
| Internal medicine | 28,450 |
| Pediatrics | 5157 |
| General surgery | 4257 |
| Obstetrics/gynecology | 12,347 |
| Orthopedic surgery | 8447 |
| Cardiovascular disease | 7687 |
| Dermatology | 7408 |
| Urology | 6043 |
| Psychiatry | 3322 |
| Neurology | 2917 |
| Ophthalmology | 19,583 |
| Otolaryngology | 3624 |
| All other specialties | 28,750 |

Not surprisingly, the calculations based on the available data suggest that primary care physicians (e.g., family practitioners, internists, OB/GYNs) are more in demand by this population than many of the specialists (e.g., psychiatry, neurology, otolaryngology). These estimates, in fact, reflect an older population that includes a lower than average proportion of children (hence fewer pediatric visits) and a higher than average proportion of seniors (hence, relatively more orthopedic, cardiovascular, and ophthalmological visits). Generating estimates in this manner allows the health demographer to use modeled data to fill a void in the existing knowledge.

Econometric forecasting addresses these factors in a series of mathematical expressions. The equation ultimately used is the one that best "fits the curve" exhibited by the historic trends. As a simple example, the historic ratios described above can be plotted as a time series and projected forward to generate a forecast. Local conditions must be examined, however, and the factors that might influence the future ratios fully understood. Former relationships between population growth in the area under consideration may suddenly change. Moreover, economic and social forces exert differing effects at different times on particular areas. Simply because a ratio has had a particular trend in the past is no assurance that it will continue to have that relationship in the future. For example, during the early decades of this century, coal mining towns in the Appalachian area grew at a faster rate than their State as a whole. However, during the past few decades, this trend has been reversed.

*Forecasts represent the most complex form of projections since they attempt to consider all possible factors that might influence population growth and change.*

An example of a technique that could be used for demographic forecasting is structural equation modeling (SEM). The two central components of SEM are the path model and the measurement model. The path model or path analysis quantifies specific cause-and-effect relationships between observed variables. The measurement model quantifies linkages between (1) hypothetical constructs that might be known but unobservable components of the phenomenon under study and (2) observed variables that represent a specific hypothetical construct in the form of a linear combination. Cause-and-effect relationships between observed variables are usually based on theoretical considerations or evidence from prior studies. However, certain conditions must be met for a variable to be designated as cause versus effect.

Once the model is fitted to data, the path coefficient (direct effect) for each path is estimated and interpreted similarly to a regression coefficient. An indirect effect of any causal variable is estimated as the product of the chain of direct effects, and a total effect is the sum of all direct and indirect effects. As with multiple regression, an effect is interpreted as the change induced by fixing other variables in a model and changing only the subject variable. A direct effect would occur if all other variables in a model remained constant. In estimating an indirect effect, all other variables in the model are controlled except for the mediating variables in the path representing the indirect effect of interest. Observed variables should be both valid and reliable with respect to measurement of the latent variables.

The relationships in structural equation modeling are usually formulated by linear regression equations, and can be graphically expressed by path diagrams. The distinct advantages of this technique compared to other statistical methods are the ability to test construct-level hypotheses and provide interpretation based on the analysis. As an example, this method could be used to explain the factors that determine a health index for an individual or, more appropriately, a population. A health index is often used as an indicator of the level of health of a community or a country. These indexes are influenced by the health status of individuals within the community. Besides being often used as an indicator of the state of welfare of a country, the health index may also indicate its level of productivity and economic growth. If the relationship of the indicator variables with their respective latent variables can be determined the contributors to the health index can be identified.

This appears to be a particularly useful technique for forecasting demographic-related phenomena. The health of a population is influenced by factors that are related to the economy and the environment, as well as social and biological factors. Some of these factors are observable and some are not. The factors that are not directly observed, such as lifestyle, socio-demographic attributes, and mental health condition can be measured through indicator variables.

Studies using this approach (e.g., Ferra, Kamarulzaman, & Abdul Aziz, 2013) have found that structural equation modeling is a useful technique for generating demographic-based forecasts of health phenomena.

## 9.5 The Impact of Population Change

Changes in population size almost invariably result in changes in population distribution and population composition. Differential birth and death rates may cause changes in both the distribution and composition while the distribution of in-migrants may exhibit different patterns from the population in the receiving community. Migrants, in fact, affect the population composition of both the communities from which they originate and those to which they migrate.

In the United States historical migration patterns have contributed significantly to the redistribution of the U.S. population. Migration from the eastern portions of the nation to the western portions has been a constant phenomenon since the continent's first settlers. More recently, migration from the Northeast and Midwest to the South and West regions has dramatically reshuffled the distribution of the nation's population and reshaped its social tapestry. Other examples of the impact of migration on the U.S. population include the migration streams of primarily African-Americans from the South to the Midwest and Northeast during the period of agricultural mechanization during the first half of the 20th century and the dispersion of the Hispanic population throughout the U.S. since the 1990s. While Hispanics (particularly Mexican-Americans) remain concentrated in the West and southwestern states, migration over the past two decades has resulted in the spread of this population across the nation to the point that virtually every U.S. county counts Mexican immigrants among its residents.

*A change in population size often involves changes in population distribution and population composition.*

Change in population size typically involves changes in the composition of the population affected by the change. There are a few situations in which the population composition remains constant over time even as residential turnover occurs. Examples include a single-family neighborhood with facilities geared toward young families in which the residents' characteristics remain constant over time as new young families replace older families whose housing needs have changed. Or the retirement community that has age restrictions and perhaps other requirements of its residents to assure a consistent demographic mix for the community.

In most cases, however, it is expected that population turnover will be accompanied by changes in population composition. This has been demonstrated time after time in our urban centers as wave after wave of successive immigrant groups have one after another replaced each other, thereby significantly changing the character of the community or as “urban pioneers” replace long-time residents in inner-cities through the gentrification process causing old-time residents to bemoan the fact that the neighborhood is “not like it used to be.” An important role for applied demographers involves the ability to anticipate the implications of population change, and Case Study 9.2 describes the impact on residential turnover on population composition.

**Case Study 9.2: Population Turnover and Compositional Change**

When population change occurs it not only affects the size of the population but also has implications for population distribution and composition. Whether the change is engendered by persons added to the population through birth or in-migration or persons subtracted from the population through death or out-migration, population size, distribution and composition are inevitably affected.

A case in point is an older suburban area on the fringe of the inner city in a medium-sized Southern city. The Taylor community had been established during World War II as an industrial community of middle- and working-class families. It maintained this status until the 1970s when the last plants closed and jobs disappeared from the community. The decline of industry coincided with the beginning of the movement of inner-city residents into near suburbs and the subsequent flight of white residents to more distant residential areas.

The residential turnover that occurred between 1980 and 2010 had a major impact on the composition of the residents of the Taylor community. This analysis focuses on the two decades between 1990 and 2010 in an effort to understand the compositional changes occasioned by the turnover the community experienced. In terms of population size, there was little change over the two decades with the number of people residing in the community in 2010 little different from that in 1990. The distribution of the population geographically within the community changed little over these two decades as well, since the area was essentially “built out,” and there was little space for additional residential development.

A major shift, however, was noted in the composition of the population. By the time the influx of inner-city residents was underway, the original Taylor population had aged considerably, with many of the original “settlers” from the 1950s and 60s aging in place. Older residents made of the bulk of community members with older working-age residents and seniors being more common in 1990 among long-time residents while the younger age cohorts (e.g., ages 5–34) were overrepresented among the newcomers. Interestingly, the sex ratio exhibited little change over this two-decade period.

The most important change was recorded for the racial mix. In 1990 the white population still maintained a slight edge (55%–45%), but by 2010 the population was 89% black and 11% white. No other racial or ethnic group was represented to any extent. This racial turnover was accompanied by a number of other changes. The proportion of the population that was married dropped from 55% to 32% (with one-fourth of the latter being separated). The proportion never married increased from 28% to 51%. The proportion of family households declined from 79% to 71% and the proportion of female-headed households with children increased from 17% to 26%.

Similar dramatic changes were recorded over the two decades for a number of other attributes. The median household income actually declined between 1990 and 2010 (from $23,270 to $21,367) as did the median family income (from $27,942 to $24,750). At the same time, the poverty population increased dramatically, with the proportion of persons living at or below poverty increasing from 20% to 61%, the proportion of poverty-level families from 17% to 36% and the proportion of impoverished children under 18 from 21% to 63%.

These changes in socioeconomic status reflected a decline in labor force participation overall (from 67% to 62%) but an increase in female labor force participation (from 24% to 44%). The already high unemployment rate increased dramatically (from 15% to 40%). The educational level did not increase over this time period and actually declined slightly.

Clearly, as a result of population change, the population of Taylor looked a lot different in 2010 than it did in 1990. It was transformed from an older, predominantly white moderately educated middle and working-class population of stable families into a predominantly younger African-American lower- to working-class population with limited education and high rates of unemployment. While the overall size of the population and its distribution felt limited effect from the population turnover that occurred, the community's population composition was significantly altered.

## 9.6 Data Sources for Population Change

Demographers have long used population estimates and projections in the absence of actual data, and a variety of techniques are utilized for these purposes. Population estimates for states, MSAs, and counties are prepared each year as a joint effort of the Census Bureau and the state agency designated by each state governor under the Federal-State Program for Local Population Estimates (FSCPE). The purpose of the program is to standardize data and procedures so that the highest quality estimates can be derived. Most states also generate population estimates and projections that are available through state agencies. However, these figures are often produced at irregular intervals, and thus may be quite dated.

Population estimates and projections generated by government agencies have historically been the only ones available. Today, however, a number of data vendors provide these figures. These vendor-generated data are often made available down to small units of geography (e.g., the census tract) and in greater detail (e.g., sex and age breakdowns) than government-produced figures. They offer the flexibility to generate estimates and projections for "custom" geographies (e.g., a market area) not available for government-generated statistics. The drawback, of course, is that some precision is lost as one develops calculations for lower levels of geography and for population components. However, the ease of accessibility and timeliness of these vendor-generated figures have made them a mainstay of health planners and researchers.

Issues have been raised concerning the quality of the synthetic data produced by both government agencies and commercial data vendors. Data users typically need the latest information possible, and in an effort to be expedient the question of quality sometimes has become a secondary concern. Any evaluation of the quality of synthetic data requires knowledge of the date and quality of the historical data being used as a basis for the estimates and projections. Furthermore, attention must be paid to the methods and assumptions utilized to generate the figures. If, for example, one assumes that population growth in an area is gradual and can be described by a simple mathematical function, population estimates and projections will be reasonably accurate as long as the assumptions hold. However, to the extent that an assumption is wrong, the (incorrect) mathematical function will yield inaccurate estimates and projections. While it is not possible to be aware of all the nuances of data quality and method, users are urged to evaluate underlying assumptions critically and to ascertain the accuracy of the synthetic data that are available.

**Exercise 9.1: Constant Change Projections**

There are two ways in which a constant change technique can be used to generate population projections: numerical change and percentage change. For the community featured below examine the data provided and compute projections using these two different techniques. Discuss how the outcome differs depending on the technique used.

Model 1: Numerical change

$$\text{Population } T_{1990} = 10,000 \quad \text{Population } T_{2000} = 20,000$$
$$\text{Population } T_{2010} = \_\_\_\_\_\_\_\_\_\_\_$$

Calculate the average annual numerical change between 1990 and 2000. Apply this figure to the period between 2000 and 2010 and calculate the 2010 population.

Model 2: Percentage change

$$\text{Population } T_{1990} = 10,000 \quad \text{Population } T_{2000} = 20,000$$
$$\text{Population } T_{2010} = \_\_\_\_\_\_\_\_\_\_\_$$

Calculate the average annual percentage change between 1990 and 2000. Apply this figure to the period between 2000 and 2010 and calculate the 2010 population.

Examine the two outputs and determine how they differ. Plot the trends using an Excel spreadsheet or other tool and compare the slopes generated by the two techniques.

**Exercise 9.2: Calculating Population Change**

You have been asked to calculate population change for Podunk County in order to develop plans for school expansion. Calculate population change first by looking only at natural increase and, then, by including migration in the equation.

Calculate the missing values for Podunk County based on natural increase for a future year and for a past year:

| 2005 Population | Births 2005–2014 | Deaths 2005–2014 | 2015 Population |
|---|---|---|---|
| 50,000 | 500 | 200 | ________ |

| 2005 Population | Births 2005–2014 | Deaths 2005–2014 | 2015 Population |
|---|---|---|---|
| ________ | 500 | 200 | 30,000 |

Calculate the missing values for Podunk County based on natural increase AND migration:

| 2005 Population | Births 2005–2014 | Deaths 2005–2014 | In-Migration | Out-Migration | 2015 Population |
|---|---|---|---|---|---|
| 50,000 | 500 | 200 | 1000 | 200 | ________ |

| 2005 Population | Births 2005–2014 | Deaths 2005–2014 | In-Migration | Out-Migration | 2015 Population |
|---|---|---|---|---|---|
| 50,000 | 500 | 200 | 200 | 800 | ________ |

| 2005 Population | Births 2005–2014 | Deaths 2005–2014 | NetMigration* | 2015Population |
|---|---|---|---|---|
| 50,000 | 500 | 200 | ________ | 60,000 |

*Net migration = Difference between in-migration and out-migration

**Exercise 9.3: Housing Unit-Based Estimates**

Students are tasked with the job of estimating the population for Smith County for 2015 using a reality-based approach. Information is available on the number of housing units of various types in the county in 2010 based on the decennial census. Information is available from local sources on the new housing units that have been added since 2010. Estimates of the average household size can be obtained from the American Community Survey (ACS). Using the information provided, generate an estimate of the 2015 population of Smith County.

| Housing Type | Number | Average Household Size | Added Population |
|---|---|---|---|
| Single-family home | 1000 | 3.00 | _______ |
| Apartments | 500 | 2.00 | _______ |
| Mobile homes | 50 | 2.50 | _______ |
| Total population added between 2010 and 2015 | | | _______ |

Smith County 2015 Population = 20,000 + [added population] = ____________

*Note* This exercise does not take into consideration housing stock that has been removed from the total between 2010 and 2015

## References

Ferra, Z., Kamarulzaman, I., & Jemain, A. A. (2013). Bayesian structural equation modeling for the health index. Downloaded from URL: https://ukm.pure.elsevier.com/en/publications/bayesian-structural-equation-modeling-for-the-health-index.

Swanson, D. A., & Tedrow, L. (2017). *The top ten reasons to use the cohort change ratio method*. Downloaded from URL: file:///C:/Users/Thomas%20pc/Desktop/SWANSON%20&%20TEDROW%20PAA%202016%20V1%20(2).pdf.

Thompson, W. S. (1929). Population. *American Journal of Sociology, 34*(6), 959–975.

## Additional Resources

Baker, J., Swanson, D. A., Tayman, J., et al. (2017). *Cohort change ratios and their applications*. New York: Springer.

Booth, H. (2006). Demographic forecasting: 1980 to 2005 in review. *International Journal of Forecasting, 22*(3), 547–581.

Girosi, F., & King, G. (2008). *Demographic forecasting*. Princeton, NJ: Princeton University Press.

Population Reference Bureau (2001). Understanding and using population projections." Downloaded from URL: http://www.prb.org/Publications/Reports/2001/UnderstandingandUsingPopulationProjections.aspx.

Smith, S. K., & Tayman, J. (2008). *State and local population projections: Methodology and analysis*. New York: Springer.

Taylor and Frances On-Line. *Structural Equation Modeling: An Interdisciplinary Journal*.