Bayesian Demography: Projecting the Iraqi Kurdish Population, 1977–1990

Beth Osborne DAPONTE, Joseph B. KADANE, and Lara J. WOLFSON

Projecting populations that have sparse or unreliable data, such as those of many developing countries, presents a challenge to demographers. The assumptions that they make to project data-poor populations frequently fall into the realm of "educated guesses," and the resulting projections, often regarded as forecasts, are valid only to the extent that the assumptions on which they are based reasonably represent the past or future, as the case may be. These traditional projection techniques do not incorporate a demographer's assessment of uncertainty in the assumptions. Addressing the challenges of forecasting a data-poor population, we project the Iraqi Kurdish population using a Bayesian approach. This approach incorporates a demographer's uncertainty about past and future characteristics of the population in the form of elicited prior distributions.

KEY WORDS: Census data; Cohort–component projections; Elicitation; Forecasting; Population; Population projections; Subjective opinion; Vital rates.

1. INTRODUCTION

The problem of forecasting populations haunts demographers. To assure readers that they cannot forecast, demographers instead "project" populations, meaning that given a set of assumptions, demographers perform the arithmetic for the users of their figures. However, "a demographer makes a projection, and his reader uses it as a forecast; does the demographer's intention or the reader's use determine whether projection or forecasting has occurred?" (Keyfitz 1972, p. 353). We, like others before us (Hoem 1973; Keyfitz 1972; Stoto 1983) regard the class of population projections that use the most likely scenario as forecasts. Other classes of projections performed to demonstrate the result of hypothetical or unlikely circumstances should not be considered forecasts, but merely arithmetic exercises.

Population forecasts are used for two purposes: to suggest what a population will look like in the future, and to suggest what the population has looked like in the past when data of reasonable quality for the period are not available. Given that in fact demographers often forecast populations, this article presents a method to create forecasts that model a demographer's uncertainty about the forecast.

In this article we expand on the work of Pflaumer (1988) and take Land (1986) up on his suggestion to integrate statistical and demographic methodologies in performing population projections. Land wrote that "statisticians and demographers need to take a much more statistical perspective on population forecasting. A full statistical forecast of an uncertain future population quantity even if based entirely on informed expert judgments would be a probability density for it... .This suggests, for instance, that it would be instructive to examine the implicit Bayesian decision theoretic basis that lies beneath the production of projection intervals..." (p. 899). We also show how current methods used by demographers can be adapted to integrate a Bayesian approach.

The Bayesian approach expresses uncertainty in terms of probability distributions. These distributions generally reflect the views of the analyst, although in some cases they can model the views that others do or might hold. Because they represent personal opinion, they are referred to as "personalistic" or "subjective" in the Bayesian literature (Savage 1954, p. 27).

Conducting Bayesian demographic analysis promises three important advantages. First, utilizing this approach would enhance communication among demographers. Making one's beliefs explicit using probability distributions allows other demographers to observe exactly how one views the sources of uncertainty in the phenomenon. Others can then know on what they agree or disagree. The reasons given for particular probability distributions can be an important source of insight. The second important advantage of Bayesian demographic analysis pertains to the user. The consequence of the explicitly probabilistic inputs is explicitly probabilistic output. Population "projections" become forecasts with explicit probability distributions. These can be used in whatever inference or decision the users face, if the input probabilities are acceptable.

A third advantage of a Bayesian analysis is its greater flexibility in reflecting demographic beliefs. Classical models either include or exclude a parameter about which no prior is expressed, which is often equivalent to expressing certainty about its value. Using probability distributions permits one to express states of knowledge in between these two alternatives.

Hyppölä, Tunkelo, and Törnqvist (1949) (see also Tornquist's appendix in Hoem 1973) preceded us in developing

Beth Osborne Daponte is Research Associate, office of Child Development, University Center for Social and Urban Research, University of Pittsburgh, Joseph B. Kadane is Professor of Statistics and Social Sciences, Department of Statistics, Carnegie Mellon University, Pittsburgh, PA 15213. Lara J. Wolfson is Assistant Professor, Department of Statistics and Actuarial Science, University of Waterloo, ON, Canada N2L 3G1. The authors thank Peter Johnson of the U.S. Census Bureau for helpful conversations and for sharing the computer software projection package, RUP, and Joost Hiltermann, Shorsh Resool, and Middle East Watch for sharing their knowledge and materials on the Iraqi Kurdish population. A special thanks to Heidi Rhodes Sestrich for her patient secretarial support. The authors also thank Sam Preston, Noreen Goldman, and the referees for their helpful comments on previous versions of this article. This research was supported in part by National Science Foundation grants DMS-9303557 and SES-9123370 and by Office of Naval Research Contract N00014-89-J-1851.

Journal of the American Statistical Association
December 1997, Vol. 92, No. 440, Applications and Case Studies

a subjective approach to population forecasting. To forecast the population of Finland to the year 2000, they used the 20th, 50th, and 80th percentiles of their (subjective) fertility distributions, together with what they took to be pessimistic, most likely, and optimistic assumptions about mortality, to produce what they took to be the 10th, 50th, and 90th percentiles in the resulting population, but they had no firm basis for this claim. We think that Hyppölä et al. were years ahead of their time in what they wanted to do and, had they had access to adequate computing power, they might have performed a forecast similar to the one we present herein.

This article offers a case study in projecting the Iraqi Kurdish population under a certain hypothetical scenario explained later. We first discuss current practices in performing population forecasts. We then consider ways that others have proposed to integrate uncertainty into the forecasts. We conduct a forecast of the Kurdish population of Iraq from 1977–1990 that integrates Bayesian and demographic analysis. To conclude, we present summary results for the projection. We project the Iraqi Kurdish population only to 1990, so one can consider what the Iraqi Kurdish population would have looked like prior to the 1991 Persian Gulf War had the repression of the Kurds since 1977—and particularly the Anfal (a state-sponsored campaign of violence against the Iraqi Kurds described later)—not occurred. This projection is part of a larger project that has the goal of estimating the detrimental demographic effects attributable to the Anfal and other oppression of the Kurds. The specific effects estimated (e.g., excess mortality and diminished fertility) depend on the form of data on the post-Anfal Kurdish population. For example, the population projection reveals the number of Iraqi Kurds that would have died had "normal" mortality levels prevailed. If and when data on actual mortality among Iraqi Kurds during this time period become available, the magnitude of excess mortality can be calculated. Thus the population that we project is hypothetical.

The Iraqi Kurdish population lacks high-quality data, making it similar to the populations of many developing countries. Demographers studying the populations of developing countries are often confronted with fragmentary or incomplete information on the population. This is the case in the Lesotho highlands water project, which successfully applied this methodology (Daponte and Wolfson 1995).

2. CURRENT PRACTICES

In any population projection, a demographer makes a number of decisions with respect to the population processes involved. These decisions are subjective guesses of what is most likely to occur based on what already has occurred in the population and on professional opinion.

The first decision a demographer makes when projecting a population is which type of projection to perform. Although mathematical functions are sometimes used (Smith and Sincich 1990), in general the cohort-component method is the preferred procedure (Arriaga and Associates 1993, p. 309). The U.S. Census Bureau, United Nations, and World Bank all perform cohort-component projections. We focus our discussion on this class of projections.

Projecting a population using the cohort-component method involves a number of steps, each of which utilizes the demographer's expert opinion. First, "a component projection requires a population properly distributed by sex and age to serve as the base population for the starting date of the projection" (Arriaga and Associates 1993, p. 314). This population is usually based on the most recent census, "moved" from the census date to midyear (July 1) and adjusted for underenumeration and overenumeration and for age misreporting. The raw census data are evaluated in light of recent fertility and mortality surveys. The demographer relies on scientific knowledge and experience to judge the quality of the raw data and makes proper adjustments subjectively. Where one demographer may adjust the data in a certain way to meet his or her interpretation of "proper," another may adjust the data differently.

Second, the demographer makes assumptions regarding the levels and patterns of fertility that will (or have) prevail(ed) since the census date. Often, the level of fertility (total fertility rate) is projected and then a pattern of fertility (age-specific fertility rates) is assumed. A similar process is used to project mortality, where the demographer projects the general level of mortality (expectation of life at birth) by sex and then assumes age-specific mortality rates (Arriaga and Associates 1993). Finally, levels and patterns of net migration are assumed. The projected levels and patterns of the components of population change are applied to the base population to yield the projected population for a given year.

Uncertainty is introduced into the forecast in a number of ways. At all stages in the process, a demographer uses judgment based on professional experience to arrive at the most "reasonable" set of future demographic indices. Projecting a population becomes an art influenced by scientific techniques. Opinions, judgments, experience, and outlook are all used at various stages of the projection process. Further, the quality of the data on which the projection is based may be dubious, or data that do exist may not be available (e.g., the Iraq 1989 Subcensus of Population), leading to additional uncertainty in the projection. Also, the model may be misspecified. Hoem (1973) provided a detailed discussion of sources of uncertainty.

How is uncertainty about various elements of the projections integrated into the results? Current methods used to forecast populations generally do not allow the demographer to state explicitly his or her probability of demographic events occurring. Instead, demographers generally forecast a population using different sets of assumptions and allow the user to choose the projection that will best fit the user's needs. The range of results of projections based on various sets of assumptions is assumed to reflect "uncertainty."

> No one admits to making an arbitrary choice of assumptions for population projections; each author selects a set corresponding to the relations that he sees as persisting into the future. Since what will persist is uncertain at the time the projection is being made, he is well advised to try more than one set of assumptions and work out future numbers from each. In due course censuses will be taken in what was the future at the time the

projection was made. The hope is that the several future numbers will turn out to straddle each subsequent census, but official agencies, unwilling to present their projections as predictions, do not assign any probability that they will straddle (Keyfitz 1972, p. 353).

Current practices vary. The United Nations allows a user to choose among four scenarios: high-, medium-, low-, and constant-fertility variants, which differ primarily in the assumed future trends in fertility (United Nations 1993). The World Bank presents only one series of projections per country but rather explicitly presents the assumed changes in vital rates (World Bank 1992).

The U.S. Census Bureau projects populations two ways. The Center for International Research performs projections for every country in the world. For all countries except the very smallest, the center uses the cohort-component method. Rather than perform a number of projections under various assumptions, the center makes only one projection for each country. Users and producers of the data generally accept the projection as the most likely scenario. The center evaluates and, when it seems necessary, adjusts raw census data, even of developed countries.

The Population Division, which projects the population of the United States, produces 10 series of projections (U.S. Bureau of the Census 1992). "Although the middle series is presented in great detail, there are nine other alternative projection series" (U.S. Bureau of the Census 1992, p. xxiv). These projections begin with an unadjusted population. "This method does not correct for the net undercount in the 1990 census... The inflation-deflation variant yields a population distribution in each projected year which is similar to that which would result if a census with the 1990 pattern of undercount (as estimated by Demographic Analysis) were conducted in that year" (U.S. Bureau of the Census 1992, p. x). Therefore, rather than forecast the future expected population, the Population Division instead forecasts the enumerated population and assumes that the Census Bureau's techniques of enumerating the population will not improve or deteriorate. Among the 10 projections are three termed "high," "medium," and "low."

The logic of this approach is that the demographer presents a few main possibilities in respect of the components of population growth, shows what population will result in twenty or more years later, and leaves the selection to the user. It is up to the user to study the assumptions on which the components were projected forward, choose the set of assumptions that seems right to him, and then accept only the demographers' arithmetic to read out the resulting future population..." (Keyfitz 1987, p. 17–3).

This practice is analogous to a physician giving many alternatives for treating a disease without guiding the patient toward what the physician considers advisable. Demographers could be more useful to their readers if they more fully report their opinions, which reporting probabilities encourages and requires.

Presenting many projections does not substitute for stating the amount of uncertainty in the "medium" projection for three reasons. First, the demographer instead performs many projections, only one of which he or she thinks is most likely to occur. The other projections are generally seen as implausible or unlikely. Second, although the high and low projections take into account different future scenarios, they generally do not take into account the uncertainty in the baseline data. The projections generally start with the same data and apply different assumptions. Alho and Spencer (1985) have made some strides in this area by taking into account some, but not all, sources of error for the "jump-off" population. They assume that although there is uncertainty in the nonwhite population, the white population is perfectly known. Third, the demographer generally does not give his or her opinion of the likelihood of the other projections occurring. Are the "high" and "low" scenarios analogous to 95% confidence intervals? Stoto (1983, p. 19) found and Alho (1992) assumed that the high and low scenarios represent roughly 66% confidence intervals. Lee and Tuljapurkar (1994) assumed that U.S. high and low projection scenarios provide "perhaps a 98% confidence interval" (p. 1176). Alho and Spencer (1985) noted that the Census Bureau's "high–low forecast variants are too narrow to be interpreted as .67-level prediction intervals" (p. 313). It is unclear how the high–medium–low approach reflects uncertainty.

Hoem (1973, p. 10) wrote that "several authors have insisted that forecasters should bring the [custom of presenting several alternative forecasting series to reflect uncertainty] to an end and that they should change over to specifying probability distributions for future population numbers. Much more precise statements about forecasting uncertainty would then be possible. In principle, this type of approach evidently is a goal towards which forecasters should strive and to which one may possibly find a reasonably accurate and operational solution some time in the future."

Some demographers (Lee 1993; Lee and Carter 1992) have put confidence intervals around future estimates of components of population change by using time series methods. For example, Lee and Carter forecasted mortality with confidence intervals around future mortality extrapolations. "Their projections capture the implications of a continuation of past exponential trends in age-specific mortality rates, uncomplicated by expert opinion or assumptions about medical advances, delay of deaths by cause, or ultimate levels of life expectancy" (McKnown 1992, p. 671).

Another methodology—stochastic projection (Alho 1990, 1992; Lee 1992, 1993; Lee and Tuljapurkar 1994)—shares some of our orientation but differs from it in other respects. Lee and Tuljapurkar (1994) join us in believing that a fully stochastic analysis is preferable to the traditional high, medium, and low forecasts. However, the so-called confidence intervals that they calculated take some estimated quantities as known, ignoring standard errors of the estimates—although Lee (1994) noted that this matters only sometimes. Lee (1992) and Lee and Tuljapurkar begin their projections with a point-estimated base population, whereas our technique accounts for uncertainty in the base population. Lee and Tuljapurkar's data situation differs from ours—whereas they dealt with the relatively data-rich projection of the U.S. population, we deal with a data-poor population.

Pflaumer (1988) also shares with us the goal of stochastically projecting a population. Whereas he stated that "we prefer subjective specifications of demographic distributions" (p. 137), he actually used a piecewise uniform distribution "with no a priori information about the distribution being available" (p. 137). In his empirical example of projecting the U.S. population for nearly 100 years, he remarked, "the assumptions of the Census Bureau shall here only serve as examples to demonstrate the simulation procedure rather than to provide reliable estimates" (p. 139). Thus Pflaumer does not take scientific responsibility for the distributions that he uses.

This article represents another step toward the Tornquist–Hoem goal of stochastic projection. We advance beyond Pflaumer in that the model that we propose and the inputs that we use are subjectively determined to represent seriously considered opinion. Before applying our approach to the Iraqi Kurdish population, we provide some background.

3. THE IRAQI KURDISH POPULATION[1]

The Iraqi Kurds are an Indo-European people living in the northern reaches of Iraq. Urban Kurds live in the fertile plains, an area rich in oil and mineral resources, and rural Kurds live further north in the mountainous zones bordering Turkey and Iran. The Kurds, desiring a greater measure of self-government, have at times negotiated with and at other times fought with the Iraqi central government over the nature of their relationship.

In 1975 the Iraqi government embarked on a campaign to "arabize" Kurdish areas. The "arabization" involved relocating Arabs from southern to northern Iraq to live near and work in oil fields. The relocated Arabs, overwhelmingly males of working age, were given land and jobs. In the late 1970s, the Ba'thist regime in Baghdad, facing little opposition from the Kurdish parties, was able to create a "cordon sanitaire" in the area of its northern borders, destroying all Kurdish villages in a band approximately 15–20 km wide. After receiving symbolic compensation for their lost property, the population was moved to housing complexes in valleys closer to urban centers.

During the 1980s, the Kurds became increasingly exposed to official state violence in the wake of the Iraqi invasion of Iran and the start of the Iran–Iraq war. During this war, fought between 1980 and 1988, the Iraqi regime witnessed rural Kurdish areas slipping from its control. The *peshmergas*, guerrillas belonging to the outlawed Kurdish political parties, took advantage of this power vacuum and reasserted claims to Kurdish self-government.

In April 1987 the Iraqi regime responded by bombarding the areas over which it had lost control and systematically destroying many Kurdish villages that remained under its control. The government relocated rural Kurds to newly built housing complexes, again offering them symbolic compensation.

In the spring of 1988, as the war with Iran came to an end, the Iraqi regime launched a major military campaign against the Kurdish insurgency. The campaign, called the Anfal Operation, covered most of the Kurdish countryside. It was conducted in eight separate stages divided over a period of $6\frac{1}{2}$ months, starting in February 1988 and ending with a general amnesty decree on September 6, 1988. Stages of the Anfal Operation generally shared the following features:

- Chemical attacks on selected targets (some military and others strictly civilian).
- A massive military assault by land and by air.
- Detention of all those found in the area, including civilians, and their transfer to holding centers and from there to unknown destinations. Evidence suggests that most of those detained either were killed or died from hunger and disease while in captivity. Many women, children, and elderly persons who survived detention were released under the September amnesty.
- Complete destruction of villages in the area.

Following the Anfal, the rural areas remained off-limits to people, at penalty of summary execution. Those who survived the Anfal and benefited from the September amnesty typically spent the first several months without shelter until they obtained the resources to build a house, often in large housing complexes. Not until after the popular uprising of March 1991 (following the 1991 Persian Gulf War) and the subsequent Iraqi military withdrawal from most of the Kurdish areas 8 months later did some rural Kurds return to the sites of their villages of origin and begin rebuilding their homes.

The 1987 census played a unique role in the Anfal. Before conducting the census in October, in August 1987 the Iraqi government ordered that "steps should be taken to hold public seminars and administrative meetings to discuss the importance of the general population census scheduled to be held on October 17, 1987, and to stress clearly that anyone who fails to take part in the process without a valid excuse shall lose his Iraqi nationality. He shall also be regarded as an army deserter..." (Middle East Watch 1993, p. 86). In January 1988 a decree was issued stating that "capital punishment shall be imposed... on any deserter..."(Middle East Watch 1993, pp. 86–87). Describing the instructions for the 1987 census, Middle East Watch noted:

> The instructions were quite different from those of the five previous censuses. Those who were not included in the census would no longer be considered Iraqi nationals...; they would cease to be eligible for government services and food rations. And people could be counted only if they made themselves accessible to census-takers. For anyone living in a prohibited area, this meant abandoning one's home (Middle East Watch 1993, p. 87).

As a form of civil protest, many Kurds did not register for the 1987 census, making any estimates of the Kurdish population based on the 1987 census inaccurate. Therefore, for our projection we rely on the previous census conducted in 1977.

The Kurdish population has certain peculiarities that make estimation especially challenging. There has never been an Iraqi census that has collected data on whether

[1] The information in this section is primarily based on Middle East Watch (1993) and S. Resool (personal communication).

a person is a Kurd. However, the Iraqi Kurdish population is geographically concentrated and lives primarily in four Iraqi governorates: Arbil, Dahuk, Tamim, and Sulamaniya. To arrive at a base population of Iraqi Kurds, we first start with the unadjusted 1977 census population of these four governorates. The adjusted base population that we estimate approximates the actual 1977 Iraqi Kurdish population.

Four possible problems with the census counts of 1977 arose:

- Arabization. The "arabization" of these areas which began in the mid-1970s implies that some people living in these areas were not Kurds but instead Arabs. Rural Arabs migrated from Southern Iraq to Kurdistan because of economic incentives and generally lived near oil fields located in urban areas (Resool 1994). So, there existed the problem of removing enumerated Arabs from the population of the four governorates.
- The draft. At the time of the 1977 census, the Iraqi government drafted all males aged 18 years. To avoid military service, many Kurdish males 18 years of age would not report themselves as such. This implies that there would be disproportionately high numbers of males both younger and older than 18, but a dearth of males aged 18.
- Underreporting of females. In many developing areas where females' status is low (compared to males'), females are underenumerated. We suspect this to be the case in the four Kurdish governorates in question.
- General age misreporting. This is a problem common to the censuses of developing countries, and there is no reason to think that the Iraqi census data would be exceptional.

All four of these potential problems add to the uncertainty in our projection of the Iraqi Kurdish population. Further, there is a dearth of fertility and mortality data on Iraqi Kurds, forcing one to base estimates for the population on data for the entire Iraqi population. In the absence of data distinguishing these demographic phenomena of the Kurds from those of the Iraqi population as a whole, this approach is reasonable. The projection is performed to see what the population of Iraqi Kurds would have been in 1990 in the absence of state-sponsored violence in the 1980s.

4. OVERVIEW OF PROJECTION PROCEDURE

A Bayesian demographic projection combines expert opinion (see, e.g., Kadane, Dickey, Winkler, Smith, and Peters 1980; Wolfson 1995) with traditional demographic projection techniques (i.e., those used by the U.S. Census Bureau's Center for International Research). The projection period lasts from a base year to an end year. The cohort-component approach requires a midyear population for the base year by age and sex and for the projection period levels and patterns of migration and vital rates (fertility and mortality). Rather than have point estimates for the base population, migration, and vital rates, the Bayesian approach instead explicitly models the uncertainty inherent in these estimates by specifying distributions for them.

Rather than forecast into the future, the forecast goes from one past date to another. We have available some information on the vital rates during the forecast period. The availability of information during the projection period might make one more certain of one's estimates than one would have been without such information at hand.

We project the rural and urban populations separately to allow for differences in their demographic events. Because we do not know the form that data on the post-Anfal Iraqi Kurdish population might take, for the purpose of later evaluating the demographic effects of the Anfal (which might have had differential effects on the urban and rural populations), we choose to project the rural and urban populations separately. However, the projection program that we modified allows us to aggregate these populations, if we so choose.

The projection procedure presented computational challenges. Our procedure adapted publicly available demographic software. Specifically, source code from the U.S. Census Bureau's Rural-Urban Projection Package (RUP) and the United Nations' MORTPAK were obtained to create a Fortran program that could project a population multiple times.

5. PROJECTING THE IRAQI KURDISH POPULATION

We project the vital rates of the population, consider migration, and then arrive at a base population. The projection of fertility is addressed first.

5.1 Fertility

There is one comforting thought to offer before starting our analysis of fertility. Our analysis of the Kurdish population of Iraq is from 1977–1990, a span of 13 years. Because this represents less than one generation, fertility has only a linear relationship to our projections, not the polynomial or exponential relationship that results from projections over several to many generations. For this reason, the projections that we offer are less sensitive to assumptions about fertility than would be the case for a longer projection. Therefore, we can model fertility in a somewhat crude way and still have reasonable projections.

The fundamental quantity for understanding fertility is the age-specific fertility rate for age x at year t (ASFR_x^t), the proportion of women of age x at year t who have a child in that year. The total fertility rate in year t (TFR_t) is the sum of the age-specific fertility rates in that year; that is

$$\text{TFR}^t \equiv \sum_x \text{ASFR}_x^t.$$

It is a traditional and useful summary of overall fertility at a particular point in time.

Because no data are available on the fertility of the Kurdish population, we consider data available on Iraqi fertility. For Iraq as a whole, we use two sources of information about total fertility. (For a discussion of various fertility estimates of Iraq, see Daponte 1993b.) A 1974 survey (United Nations Economic Commission for Western Asia 1980) shows a 1974 total fertility rate (TFR) of 7.1, and the

United Nations Socio-Economic Data Sheets (United Nations Economic and Social Commission for Western Asia 1989) give a 1988 rate of 6.1.

Because we examine the Iraqi Kurdish population from 1977–1990, the first task is to estimate fertility rates for the starting and endpoint of the projection. It is likely that fertility in Iraq was decreasing; hence the 1977 rate is somewhat less than the 1974 rate of 7.1 and the 1990 rate is somewhat less than the 1988 rate of 6.1. In areas where fertility is declining and the time period is short, a logistic function should provide reasonable estimates of fertility (Arriaga and Associates 1993, p. VIII 20). Here the extrapolation of 1977 and 1990 rates was done with a logistic curve with total fertility rates asymptotes of 8 (long ago) and 2 (long into the future). Doing so yields TFRs of 7.0 for 1977 and 6.0 for 1990. We take these as the means of our fertility distributions for the start and end year of the projections. In considering sources of uncertainty of fertility in the start and end years of the projection, one should include uncertainty in how well Iraqi fertility reflects Kurdish fertility and mismeasurement error.

Next we consider urban–rural differences in fertility. The 1974 fertility survey found rural fertility to be 20% higher than urban fertility. During the projection period, we take this differential to be stochastic, with a mean of 20% (constant over time) and with a standard deviation expressing uncertainty about it. These weights are applied to the TFR for the entire country to get rural and urban TFRs.

There exists uncertainty in the TFRs obtained for the rural and urban areas—mean TFRs in 1977 of 7.6 in rural and 6.4 in urban and in 1990 of 6.5 in rural and 5.5 in urban. We model this uncertainty as a standard deviation; sources of uncertainty include doubts as to whether the 20% rural–urban differential remained constant over time, concerns over the initial measurement of fertility, and concerns over whether the logistic interpolation yields correct TFRs. In considering the mismeasurement issue, Daponte (1992) evaluated Iraqi fertility using several demographic techniques applied to the relevant data sources. Based on her evaluation of Iraqi fertility and the sources of uncertainty mentioned earlier, we set our 95% credible intervals of the TFR 6.0–6.8 in 1977 and 5.15–5.85 in 1990 for urban areas, and 7.1–8.1 in 1977 and 6.1–6.9 in 1990 for rural areas, with normal distributions assumed for convenience and because they reasonably represent our beliefs.

Hence our evaluation of the marginal densities of urban and rural fertility in 1977 and 1990 fertility is presented in Figure 1.

To specify a joint normal distribution with marginal densities shown in Figure 1, it is necessary to specify correlations. We assume that the TFRs, both urban and rural, are uncorrelated in the base and end years. Further, we take the correlation between rural and urban TFRs in both the base and end years to be 1, because the major source of our uncertainty about the TFRs is measurement error, which would apply equally to both urban and rural areas in both 1974 and 1988.

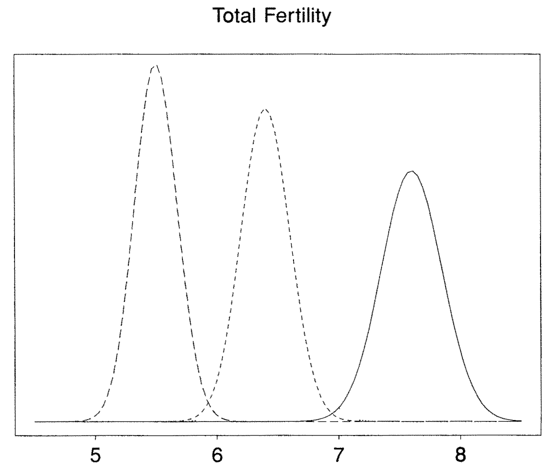

Figure 1. Probability Density Function of Elicited Total Fertility Rates, 1977 and 1990, for Urban and Rural Areas. From left to right, pdfs are for urban areas, 1990 (– – –) [N(5.5, (0.175)^2)], urban areas, 1977 (- - -) [N(6.4, (0.2)^2)], rural areas, 1990 (· · ·) [N(5.6, (0.2)^2)], and rural areas, 1977 (——) [N (7.6, (0.25)^2)].

Thus the vector (TFR^U_{77}, TFR^R_{77}, TFR^U_{90}, TFR^R_{90}) (with superscripts indicating urban and rural), is taken to be jointly normal, with margins specified in Figure 1 and correlation matrix

$$\begin{bmatrix} 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 1 \end{bmatrix}$$

This completely specifies their joint distribution.

Having drawn values of the base and end year urban and rural TFRs from this distribution, we extrapolated them for the intervening years using the logistic function in RUP, which uses an upper asymptote of 1 + max (6, TFR_{77}, TFR_{90}), and a lower asymptote of 2. Thus we obtain a (stochastic) series of urban and rural TFRs from 1977 to 1990.

The next step in the analysis is to distribute the TFR by age. The 1974 fertility survey (United Nations Economic Commission for Western Asia 1980) is unique, in our view, among data sources in giving reasonable fertility patterns by age for Iraq. Dividing the 1974 ASFRs by the TFR_{74} yields the proportion of the TFR contributed by women of each age. Those proportions are reported in Table 1 separately for urban and rural Iraq.

Alternatively, one could model the age pattern of fertility as uncertain. We do not do so here, because the level of fertility did not change drastically since 1974, and introducing uncertainty about the age pattern of fertility would have little effect on the results.

Assuming that the fertility pattern reflected in Table 1 is constant for the 13 years in question, multiplying the weights for age x in Table 1 by TFR_t yields an estimate for ASFR^t_x. Finally, multiplying ASFR^t_x by N_x, the number of women of age x, yields an estimate of the number of births in year t to women of age x. Summed over mothers' ages x, this gives an estimate of the number of births in year t.

Table 1. Proportional Fertility Rates Per Year

Age	Urban	Rural
15–19	.0172	.0199
20–24	.0447	.0440
25–29	.0479	.0459
30–34	.0407	.0392
35–39	.0306	.0301
40–44	.0140	.0157
45–49	.0048	.0052

NOTE: Rates by age and location for Iraq (From United Nations Economic Commission for Western Asia 1980).
Source: Calculated from age-specific fertility.

5.2 Mortality

The existing mortality data for the Kurdish population is also limited. Thus indirect estimation techniques must be used to obtain estimates of mortality between 1977 and 1990. Because far more is known about the Iraqi population's infant and child mortality levels than about adult mortality, indirect estimates of age-specific mortality rates over the life cycle are based on infant and child mortality.

The best estimates of Iraqi infant mortality for the latter half of the twentieth century have been provided by Jones (1992), who reviewed mortality estimates for Iraq. Jones provided a series of infant mortality rates for both sexes combined based on reconciling mortality estimates from various survey and census data. He gave an infant mortality rate (IMR) of 39 per 1,000 live births in 1990, which we use as the mean of our distribution for IMR in 1990. He also gave IMRs of 75 for 1975 and 63 for 1980. We slightly prefer the estimate of 70.4 for 1977 given by a logistic fit (using FITL-GSTC, Version 100 of the U.S. Bureau of the Census) to the estimate of 70.2 for the same year that comes from a linear extrapolation. Sources of uncertainty in the IMR include measurement error, questions about the appropriateness of using Iraqi IMRs for the Kurdish population, and basic uncertainty in Jones's evaluation of mortality. Figure 2 illustrates the densities, means, and standard deviations of the IMRs for both sexes combined for the base and end years of the projection. Again normality is assumed, both for simplicity and as a reasonable representation of belief. Also, 1977 and 1990 IMRs are taken to be independent.

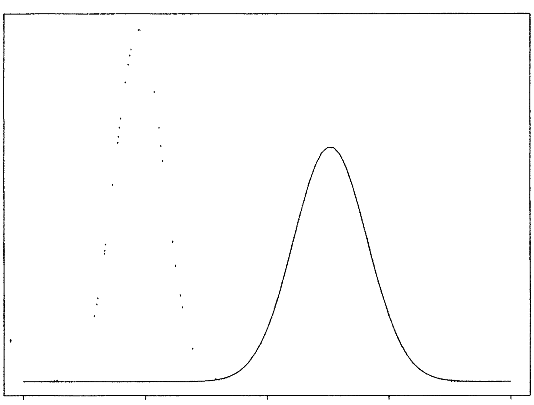

Figure 2. Probability Density Function of Elicited Joint Infant Mortality Rates (IMR). · · ·, the pdf of the 1990 IMR (μ = 39; σ = 4); ——, the 1977 IMR (μ = 70:4. σ = 6).

Table 2. Elicited Quantiles of Δ_{MF} Conditional on IMR

	Quantiles of Δ_{MF}		
IMR	50th	75th	97.5
90	0	4	12
70	−2	1	7
50	−4	−2	2
30	−6	−5	−3

Next, the sex differential in infant mortality is considered. In 1989, the United Nations (United Nations Economic and Social Commission for Western Asia 1989, p. 55) reported that the IMR in Iraq in 1988 was 62.5–63.4 for males and 61.6 for females. The level of the IMR was based on the UN's analysis of children ever born/children surviving information from the 1974 fertility survey, a 1980 survey, and the 1987 census. This level is substantially higher than that reported by Jones (1992), because the UN had not yet incorporated data from more recent surveys on child health conducted in 1989 and 1990 (Republic of Iraq 1990; UNICEF 1990). The UN bases its sex differential in infant mortality on 1987 census data on infant mortality. We rely on the survey data for the level of infant and child mortality and on the UN's estimates for the sex differential in mortality.

Based on these fragmentary data, one can model the sex differential, $\Delta_{MF} = IMR_F - IMR_M$, the difference between female and male infant mortality rates. As mortality decreases, the tendency for excess female mortality also decreases (Hill and Brown 1994; Langford and Storey 1993). Considering Δ_{MF} at four distinct points of the IMR—90, 70, 50, and 30—we modeled Δ_{MF}'s uncertainty as follows.

Here we express the belief that the uncertainty decreases as the IMR decreases. These values indicate that both the mean and standard deviation of the resulting normal distribution are linear in IMR, so the conditional distribution of Δ_{MF}, given IMR, is a normal distribution with mean and standard deviation:

$$\hat{\mu}(\Delta_{MF}) = .1 \times \text{IMR} - .9$$

and

$$\hat{\sigma}(\Delta_{MF}) = .059 \times \text{IMR}. \quad (1)$$

That (1) fits the elicitations reported in Table 2 exactly is convenient but not necessary.

After sampling the IMR from the normal distribution defined in Figure 2, a conditional value of Δ_{MF} is sampled from (1). From this, the IMRs for each sex are obtained using a sex ratio at birth of 1.05 as:

$$\text{IMR}_F = \text{IMR} - \left(\frac{1.05}{1+1.05}\right)\Delta_{MF} \quad (2)$$

and

$$\text{IMR}_M = \text{IMR} + \left(\frac{1}{1+1.05}\right)\Delta_{MF}. \quad (3)$$

Because we project the rural and urban populations separately, we next consider the differential in mortality between the urban and rural populations. A 1974 survey

(United Nations Economic Commission for Western Asia 1980) showed no difference between mortality rates in rural and urban areas. However, our analysis of recent data collected by the International Study Team (1992) indicates that between July 1985 and July 1990, children in urban areas had a substantial survival advantage over their rural counterparts—IMRs of $\sim$33 and 44. This difference seemed too large to be believed, so we examined the urban–rural mortality differential in Jordan, a country socioeconomically similar to Iraqi Kurdistan. The 1990 Jordan Population and Family Health Survey (Zou'bi 1992) showed that infants in urban areas had an approximate 10% survival advantage over rural infants, a level that seemed more credible. Because this seems more reasonable, we assume that when compared to Kurdish rural infants, the IMR among urban Kurds will be approximately 10% lower, although we are uncertain about this assumption.

The difference between rural and urban infant mortality rates is

$$\Delta_{RU} = \frac{\text{IMR}_{\text{RURAL}} - \text{IMR}_{\text{URBAN}}}{\text{IMR}_{\text{URBAN}}} \tag{4}$$

This difference we model as normally distributed with a mean and standard deviation as follows:

$$\hat{\mu}(\Delta_{RU}) = .1; \hat{\sigma}(\Delta_{RU}) = .05. \tag{5}$$

To establish some additional notation, let R be the rural population, U be the urban population, $r = R/(R+U)$ be the rural proportion, and $u = U/(R+U)$ be the urban proportion. Because the IMR for an entire area is a weighted average of the $\text{IMR}_{\text{RURAL}}$ and the $\text{IMR}_{\text{URBAN}}$, for a given sex the rural and urban infant mortality rates are computed as

$$\text{IMR}_{J,\text{RURAL}} = \frac{1+\Delta_{RU}}{r(1+\Delta_{RU})+u}\text{IMR}_J \tag{6}$$

and

$$\text{IMR}_{J,\text{URBAN}} = \frac{1}{r(1+\Delta_{RU})+u}\text{IMR}_J, \tag{7}$$

where $J = F, M$.

The proportion of the population living in rural areas in 1977 is .51, and this proportion is kept constant throughout this projection. A more precise approach would have this proportion vary based on the midyear geographic distribution of the population for each of the projection years. Considering that our point estimate projection showed 51% of the population in rural areas in 1990, in our view correcting this extremely minor source of error would not have produced results much different from the ones that we present.

Once rural and urban infant mortality rates by sex have been determined, one needs to estimate mortality at other ages in the life cycle. Although Kohli (1976) provided life tables for Iraq, an evaluation of these life tables showed them to be implausible, especially with respect to the mortality estimates of rural females. His life tables were essentially based on a newly developed incomplete vital registration system, and Kohli himself wrote that the table should be interpreted with caution (p. 16). We do not use these life tables or any information contained in his article for our analysis. The existence of contradictory mortality estimates demonstrates the extent of uncertainty in the estimates.

The South model of life tables assumes "high mortality under age 5, low mortality from about ages 40–60, and high mortality over age 65" (Coale and Demeny1966, p. 14), which describes the situation in Iraq in the 1970s quite well. Thus we used these tables for 1977.

The West model is the model most commonly used and assumes a level of child mortality relatively lower than the South's. During the 1980s, Iraq made a concerted and successful effort to reduce its infant and child mortality. The reduction of mortality among the young makes the West model life tables appropriate in 1990; thus we use the West tables for 1990. For the 1978–1989 period, age-specific mortality rates are linearly interpolated between the two levels and patterns. We used the UN's MORTPAK computer software package to generate model life tables for each sex.

5.3 Migration

Two types of migration—interregional (international) and rural–urban—should be addressed. Considering the former type, we assume that except for the arabization of the region, Iraqi Kurdistan was neither a net sending nor a net receiving area. Other countries were not willing to accept Iraqi Kurds on a permanent basis, and Kurdistan, being a remote area, was not receiving immigrants. Since 1977, the Iraqi government used forced migration against rural Kurds three times, in the late 1970s, in 1987, and in 1988. Because our purpose is to find a distribution for the population had the Anfal and other forced migration not occurred and because natural migration was trivial, it is appropriate for this purpose not to include interregional migration in our projections.

For the period of interest, normal rural–urban migration is probably negligible. Our analysis of 1977 and 1987 Iraqi census data shows very low rates of rural–urban migration (less than 1% of the rural population per year). One cannot necessarily assume, however, that rural–urban migration rates observed for all of Iraq apply to Iraqi Kurdistan.

Even though we do not model rural–urban migration, because they have different growth rates, it is still useful to project the rural and urban populations separately. Treating the population as a whole would ignore the differences in the vital rates to which both populations were exposed, and hence result in a less accurate projection.

5.4 Obtaining a Base Population

When conducting a cohort-component projection, one starts with a base population as of July 1 categorized by 5-year age groups and sex, typically based on census data. To obtain a base population, we first take the raw data from the 1977 census and distribute persons of unknown ages according to the age distribution of persons of known ages. Next, examining the observed sex ratios

$$\text{SR} = \frac{\text{No. of males}}{\text{No. of females}}, \tag{8}$$

we observe (Fig. 3) that the sex ratios between contiguous age groups vary considerably, and that for most age groups the ratio of males to females in the population is too high, considering that neither female emigration nor excess female mortality occurred.

To resolve the variation in sex ratios between age groups, a moving average technique smoothed the ratios of the rural and urban areas separately. The sex ratios are smoothed for all ages except for the age groups 80+, 0–4, and 5–9. Although this helps the situation somewhat, the overall sex ratio was 1.19, reflecting a population that in the absence of male in-migration would appear disproportionately male. Whereas in rural areas the sex ratio is 1.10, in urban areas it is 1.28. In the absence of urban migration by males, one would expect rural sex ratios to exceed urban sex ratios because of rural–urban migration of females (Davis 1977, p. 159). The urban population in particular showed inflated sex ratios in young adults (age 15–49), typical migration ages, and we assume that these excess males are probably Arabs. The problem that presents itself, then, is how to remove Arabs living in Kurdish areas from the 1977 population.

Expected sex ratios reveal what the sex ratios of a population would be given a set of age-specific mortality rates. We calculate expected sex ratios separately for rural and urban areas for each age group by taking the ratio of the male to the female stationary populations obtained from model life tables using the IMR estimates described earlier and multiplying this ratio by the sex ratio at birth (Shryock et al. 1971, p. 221). Although we calculated expected sex ratios based on both the West model and the South model, the West model showed sex ratios that seemed too high and that reached unity too late in life. The South-expected sex ratios appeared more reasonable. Therefore, the expected sex ratios for each age group used to estimate the base population were based on the South model life tables.

When comparing the 95% credible intervals of the expected sex ratios with the enumerated sex ratios, one sees (Fig. 3) discrepancies which may be accounted for by the

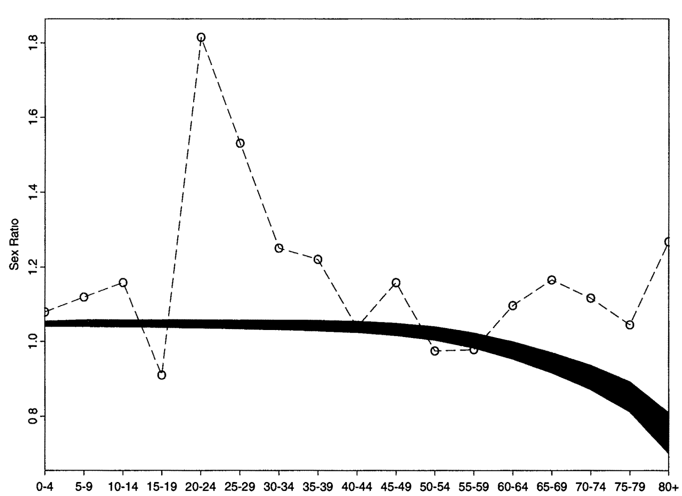

Figure 3. 1977 Sex Ratios by Age. The circles plot the enumerated sex ratios from the unadjusted 1977 Iraqi census. The solid area gives the 95% credible interval of the expected sex ratios.

following: in the rural population, an undercounting of females; in the urban areas, the inclusion of Arab men who migrated to Kurdish areas to work in the oil fields; and in both areas at draft ages, an underenumeration and age misreporting of males. All three of these factors would mask the actual Kurdish population.

To obtain an estimate of the Kurdish population in 1977 and account for these three factors, it is necessary to stochastically adjust the rural and urban populations separately using expected sex ratios. For the rural population, we generally start with the male enumerated population and adjust the figures for females based on the expected sex ratios to correct for possible underenumeration. This is done for all age groups except for those surrounding the 15–19 age group because of the draft issue and implies a 9.5%–12.5% undercount among females. For the age groups 10–14, 15–19, and 20–24, we start with the female population, adjust it upward based on the implied undercount, and then adjust the male population based on expected sex ratios.

In urban areas, for the population younger than 20, we accept the male population and adjust the female population. For the population group 20–49, we accept the female population and adjust the male population. This results in removing many men from the population, assumed to be Arab migrants. For the ages 50+, we accept the male population and adjust the female population. Because of a lack of data, no adjustment is made that might remove the presumably very small number of Arab women who might have accompanied Arab men. However, no undercount adjustment was made to women age 20–49 and, hopefully, these two factors balance. These adjustments yield a stochastically adjusted October 1977 population.

6. RESULTS

For the population projection to reflect the uncertainty in the baseline data and forecasted demographic phenomena, the projection is a Monte Carlo simulation run 10,000 times using the demographic distributions specified earlier. Considering the mortality component of the projection, the process of generating the four infant mortality rates (rural by sex and urban by sex) is repeated 10,000 times, each time taking an independent random sample from the densities specified in Figure 2 and Equations (1) and (4). The respective IMRs are then used as input to MORTPAK to obtain model life tables that contain mortality rates for the rest of the life cycle. The male and female life tables for the rural and urban areas in 1977 are used to calculate expected sex ratios for each of the areas, and then the census population (with the unknowns proportionally distributed) is adjusted based on these expected sex ratios.

Similarly, a TFR is randomly selected from the density specified in Figure 1. Although urban and rural fertility are assumed to be correlated, no correlation between fertility and mortality is assumed. If fertility rates were assumed to drop from a very high to a very low level (e.g., 7 to 2), then perhaps the assumption of independence should be reconsidered. Alho (1990, 1992) noted that zero correlation is appropriate in most cases. Age patterns of fertility, based

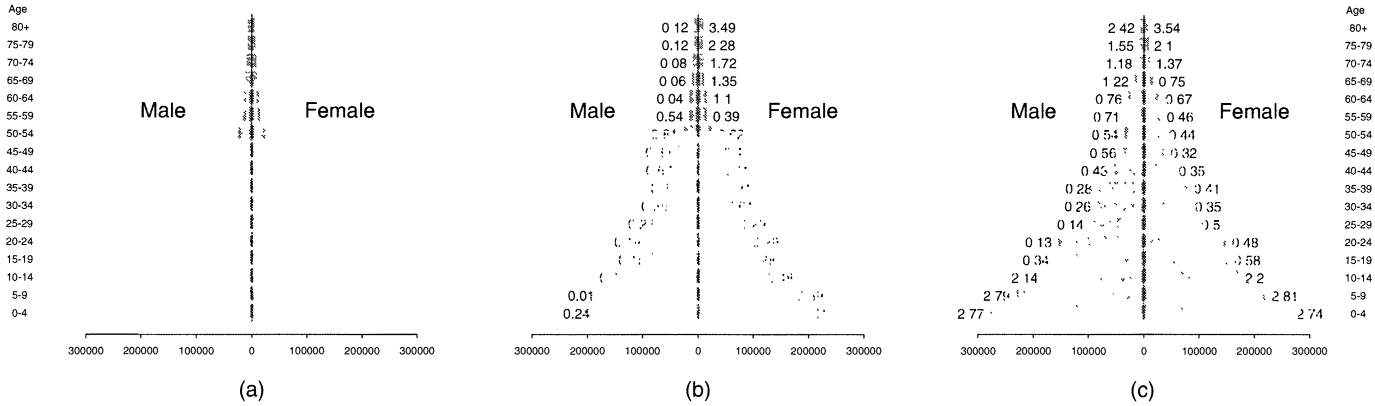

Figure 4. Population Pyramids. Solid bars on left of each pyramid represent the male population, shaded bars on right display the female population. (a). Estimated Kurdish population based on Iraqi census data, October 1977. (b) Stochastically adjusted 1977 mid-year population. (c) Stochastic 1990 mid-year population. In graphs (b) and (c), the median population of the age group is given by the bar's length; the coefficient of variation is shown numerically.

on urban and rural age-specific fertility rates reported in the 1974 survey, are proportionally adjusted to the selected TFR.

Finally, the population is "moved" from the census date of October 17, 1977, to midyear by adding in the deaths that occurred during this 3.5-month period by age and sex and subtracting births from the population under age 1. Because both the mortality and fertility rates are uncertain quantities, the adjusted October 1977 and the midyear base or populations are stochastically adjusted quantities.

Figures 4a and 4b display the population pyramids for the 1977 enumerated population and the coefficient of variation of the 1977 stochastically adjusted midyear base population. Figure 4a clearly shows the anomalies in the Kurdish population for which we adjusted. Figure 4b shows that uncertainty in the base data affects some age and sex categories more than others. Given the base data, the manifestation of uncertainty for most of the age-sex categories seems quite small.

The population pyramid for the projected 1990 population (Fig. 4c) shows that all age-sex categories are affected by the uncertainty inherent in the projected vital rates. Among age groups older than the projection period (in this case those older than age 13 years) the uncertainty in the projected population is minimal, except for the small group of elderly, where baseline 1977 uncertainty and mortality uncertainty affects the coefficients of variation. Compared with those older than the projection period and the middle-aged, the younger age groups have considerably greater associated uncertainty. Our simulations give a probability distribution for the population in each age and sex category, of which the figures are a summary.

Figure 5 displays the probability density function (pdf) of the annual exponential rate of growth over time. Due to our assumptions that as fertility and mortality decrease, the range of possible vital rates also decreases, the exponential rate of growth over time becomes more certain, as is manifested in this graph as a narrowing of the pdf.

A Bayesian approach has ramifications for the dependency ratio (defined here as the population not age 15–64 divided by the population 15–64). Figure 6 shows that the pdf of the dependency ratio flattens over time. The age distribution of the uncertainty affects this particular indicator. The pdf expands because more uncertainty is attached to the youngest age groups and, over time, these age groups in the projection period compose more of the group of people not age 15–64. Because the pdf changes considerably from year to year, the pdf over time appears wavy. The as-

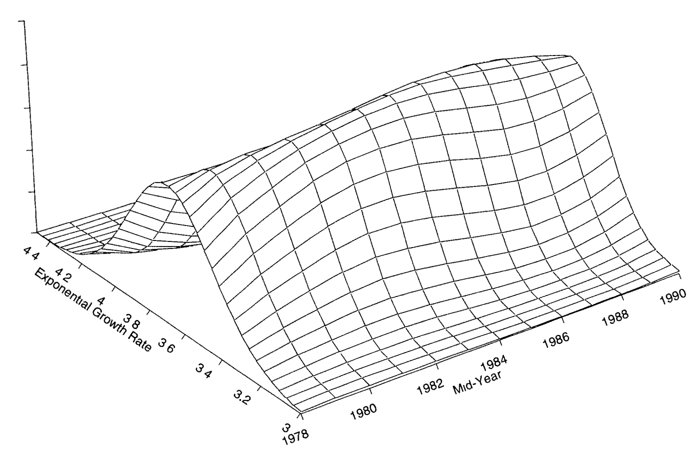

Figure 5. Probability Density Function of the Annual Exponential Rate of Growth, 1977–1990.

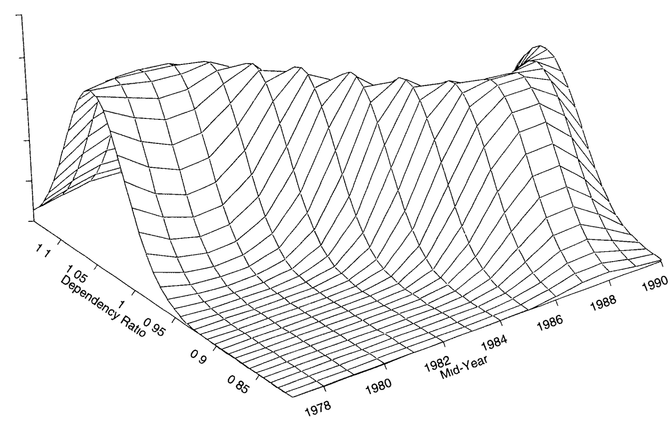

Figure 6. Probability Density Function of the 1977–1990 Dependency Ratio, the Population not Age 15–64 Divided by the Population Age 15–64.

sumptions in the projection and the changing age structure yield a slight rise in the pdf between 1989 and 1990.

To investigate the effect of the Anfal in particular on the mortality of Iraqi Kurds, one might first consider the expected number of deaths in 1988 in the absence of state-sponsored violence. Table 3 shows the range of the 95% credible interval of expected deaths by age and sex. If a tally of deaths during this period ever becomes available, then the expected range could be compared with the actual tally to estimate the number of excess deaths (see Daponte 1993).

Finally, Figure 7 exhibits the 95% credible intervals for the total rural and urban populations. The assumptions of the projection yield a somewhat narrower range of the total urban population than the total rural population. The credible interval widens over time because here the uncertainty in the estimate at one date is a function of the uncertainty in the estimate at a previous date and uncertainty in the vital rates between two dates. Information relevant to assessing the demographic impact of the Anfal on Iraqi Kurds may come in a form somewhat different than the summary measures presented here. The computer program design allows one to retrieve nearly any demographic measure and to aggregate the urban and rural populations to the total population.

The approach that we take to project a population yields a number of summary indicators. The amount of uncertainty across indicators varies, depending on which age–sex categories the indicator addresses and the length of time projected.

7. DISCUSSION

This article integrates a Bayesian approach with traditional demographic methods. Although we have demonstrated this approach using the population of a developing country, in the future we intend to apply this technique on a population of an industrialized country that has an abundance of reliable demographic data (including migration). We expect the projection of such a population to yield relatively narrow credible intervals.

Table 3. Expected Deaths, 1988; 95% Credible Interval

	Males			Females		
Age	Lower Limit	Upper Limit	Mean	Lower Limit	Upper Limit	Mean
0–4	2,096	4,355	3,169	2,007	4,049	2,991
5–9	110	300	197	113	264	186
10–14	64	169	111	65	145	104
15–19	114	291	198	136	276	207
20–24	118	291	203	140	288	214
25–29	96	226	160	95	202	149
30–34	125	275	199	113	238	175
35–39	131	264	197	117	238	178
40–44	120	211	166	111	207	161
45–49	158	244	203	158	259	213
50–54	208	301	258	225	335	286
55–59	324	440	387	382	516	458
60–64	384	503	449	63	592	538
65–69	377	462	424	451	542	504
70–74	522	603	568	613	703	664
75–79	568	628	601	656	733	698
80+	1,052	1,179	1,112	1,255	1,467	1,364

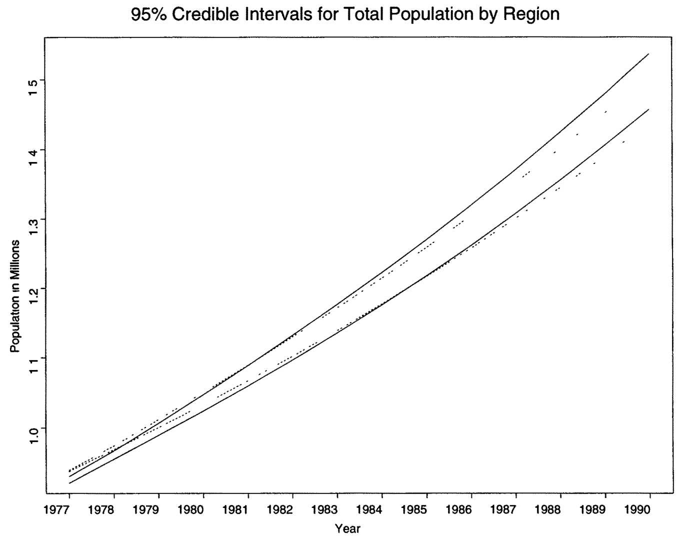

Figure 7. 95% credible intervals for total population by region and year. 95% credible intervals for the rural (——) and urban (- - -) populations.

Overall, the approach advocates that demographers consider for each component of the projection sources and magnitudes of uncertainty. We describe the decisions we made for this population, at the same time acknowledging that others may have put different weights on factors and may have made different decisions. Demographers should consider and try to model uncertainty in fertility, mortality, base population, and perhaps migration. At times, the mean and standard deviation might be based on nothing more than the demographer's educated guess, whereas at other times, the demographer might have data available that enables modeling of the uncertainty.

Rather than dismiss what is known about populations and the evaluation of data sources, Bayesian demography instead forces the demographer to confront uncertainty in the demographic phenomena and baseline data. The projection is guided by the traditional approach that demographers use to create a point estimate of the population at a future date. We believe that by encouraging demographers to state their uncertainties explicitly, the Bayesian approach offers a more precise way for demographers to communicate among themselves, and a more useful product for decision makers who use demographic projections.

[Received November 1995. Revised May 1997.]

REFERENCES

Alho, J. (1992), "The Magnitude of Error Due to Different Vital Processes in Population Forecasts," *International Journal of Forecasting*, 8, 301–314.

——— (1990), "Stochastic Methods in Population Forecasting," *International Journal of Forecasting*, 6, 521–530.

Alho, J. and Spencer, B. (1985), "Uncertain Population Forecasting," *Journal of the American Statistical Association*, 80, 306–314.

Arriaga, E. and Associates (1993), *Population Analysis with Microcomputers*, U.S. Bureau of the Census, Center for International Research.

Bogue, D. J. (1980), *Techniques for Making Population Projections: Age-Sex Projections*, Chicago, IL: Community and Family Study Center.

Reprinted as "The Components Method of Forecasting: Rationale," Chicago, IL in *Readings in Population Research Methodology*, Vol. 5, eds. D. Bogue, E. Arriaga, and D. Anderton, Editors, Chicago Social Development Center, pp. 17-7–17-10.

Coale, A. J., and Demeny, P. (1966), *Regional Model Life Tables and Stable Populations*. Princeton, NJ: Princeton University Press.

Daponte, B. O. (1992), "Iraqi Casualties From the Persian Gulf War and Its Aftermath: Technical Documentation," unpublished manuscript, H. John Heinz School of Public Policy and Management, Carnegie Mellon University.

——— (1993), "A Case Study in estimating Casualties from War and Its Aftermath: the 1991 Persian Gulf War," *PSR Quarterly*, 3, 57–66.

Daponte, B. O., and Wolfson, L. (1995), "Report on Projecting the Population of Lesotho," Unpublished report.

Davis, K. (1977), "The Effect of Outmigration on Regions of Origin," in *Internal Migration: An Internal Perspective*, eds. Brown and Neuberger. New York: Academic Press, pp. 147–166.

Hill, K., and Brown, L. (1994), "Gender Differences in Child Health: Evidence From the Demographic and Health Surveys," paper presented at the Annual Meeting of the Population Association of America, Miami.

Hoem, J. M. (1973), "Levels of Error in Population Forecast With an Appendix by Leo Thornquist," *Artikler fra Statistic Sentralbyrja*, 61, Central Bureau of Statistics, Oslo.

Hyppölä, J., Tunkelo, A., and Törnqvist, L. (1949), *Calculations Concerning the Population of Finland, Its Reproduction and Future Development*, Helsinki: Statistics Finland.

International Study Team (1992), "Infant and Child Mortality and Nutritional Status of Iraqi Children After the Gulf Conflict: Results of a Community-Based Survey," Unpublished report.

Jones, G. May 12, 1992. "Note for the Record. Iraq: Estimation of U5MR and IMR," Unpublished report.

Kadane, J. J., Dickey, R., Winkler, W., Smith, W., and Peters, S. (1980), "Interactive Elicitation of Opinion for a Normal Linear Model," *Journal of the American Statistical Association*, 75, 845–854.

Keyfitz, N. (1972), "On Future Population," *Journal of the American Statistical Association*, 67, 347–363.

——— N. (1987), "The Social and Political Context of Population Forecasting," reprinted in *Readings in Population Research Methodology*, Vol. 5, eds, D. Bogue, E. Arriaga, and D. Anderton, Chicago, Social Development Center.

Kohli, K. L. (1976), "Current Life Tables for Iraq and Its Rural Urban Areas, 1973–1974," *The Egyptian Population and Family Planning Review* 9, 15–23.

Land, K. C. (1986), "Methods for National Population Forecasts: A Review," *Journal of the American Statistical Association* 81, 888–901.

Langford, C., and Storey, P. (1993), "Sex Differentials in Mortality Early in the Twentieth Century: Sri Lanka and India Compared," *Population and Development Review*, 19, 263–282.

Lee, R. D. (1992), "Stochastic Demographic Forecasting," *International Journal of Forecasting*, 8, 315–327.

Lee, R. D., and Carter, L. R. (1992), "Modeling and Forecasting the Time Series of U.S. Mortality," *Journal of the American Statistical Association*, 87, 659–671.

Lee, R. D., and Tuljapurkar, S. (1994), "Stochastic Population Forecasts for the United States: Beyond High, Medium, and Low," *Journal of the American Statistical Association*, 89, 1175–1189.

McKnown, R. (1992), "Comment", on "'Modeling and Forecasting U.S. Mortality' by R. D. Lee and L. R. Carter" *Journal of the American Statistical Association*, 87, 671–672.

Middle East Watch (1993), *The Scourge of the Fire: A Narrative Account of the 1988 "Heroic Anfal" Campaign Against the Iraqi Kurds*, Vol. 1, Final Draft, New York: Middle East Watch.

Pflaumer, P. (1988), "Confidence Intervals for Population Projections Based on Monte Carlo Methods," *International Journal of Forecasting*, 4, 135–142.

Republic of Iraq, Ministry of Health (1990), "National Child Health Survey 1989: Preliminary Unpublished Report."

Savage, L. J. (1954), *The Foundations of Statistics*, New York: Wiley.

Shryock, H., Siegel, J., and Associates (1971), *The Methods and Materials of Demography*, Vol. I, Washington, DC: U.S. Department of Commerce Bureau of the Census.

Smith, S., and Sincich, T. (1990), "The Relationship Between the Length of the Base Period and Population Forecast Errors," *Journal of the American Statistical Association*, 85, 367–375.

Stoto, M. (1983), "The Accuracy of Population Projections," *Journal of the American Statistical Association*, 78, 13–20.

The International Bank for Reconstruction and Development/The World Bank (1992), *World Population Projections 1992–93 Edition*, Baltimore: The Johns Hopkins University Press.

United Nations (1993), *The Sex and Age Distribution of the World Populations: The 1992 Revision*, New York: United Nations Publications.

United Nations Economic Commission for Western Asia (1980), *The Population Situation in the ECWA Region: Iraq*. Unpublished report.

United Nations Economic and Social Commission for Western Asia (1989), "Demographic and Related Socio-Economic Data Sheets for Countries of the Economic and Social Commission for Western Asia as assessed in 1988," No. 6. Unpublished data.

UNICEF (1990), "Iraq Immunization, Diarrhoeal Disease, Maternal and Childhood Mortality Survey, 1990," Evaluation Series No. 9. UNICEF, Regional Office for the Middle East and North Africa.

U.S. Bureau of the Census (1992), *Current Population Reports, P25-1092, Population Projections of the United States, by Age, Sex, Race, and Hispanic Origin: 1992 to 2050*, Washington, DC: U.S. Government Printing Office.

Wolfson, L. J. (1995), "Elicitation of Priors and Utilities for Bayesian Analysis," unpublished Ph.D. thesis, Carnegie Mellon University, Dept. of Statistics.

Zou'bi, A. A. A. (1992), "Jordan Population and Family Health Survey, 1990. Amman, Jordan: Department of Statistics, Ministry of Health". Columbia, MD: IRD/Macro International.