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A FRAMEWORK FOR MULTISTATE DEMOECONOMIC MODELING AND PROJECTION, WITH AN ILLUSTRATIVE APPLICATION

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July 1982
WP-82-69

With the collaboration of Peer Just, *IIASA*, and Dennis Sams, *IMPACT Project*

Appearing simultaneously as an IMPACT Preliminary Working Paper, No. BP-31, IMPACT Research Centre, University of Melbourne, Melbourne, Australia

Paper presented at the American Statistical Association/ Bureau of the Census International Conference on Forecasting Regional Population Change and Its Economic Determinants and Consequences, Airlie, Virginia, 26-29 May 1982.

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PREFACE

The ways in which our society may have to adapt and respond to changes induced by energy shortages, environmental ceilings, and food insufficiencies has been the subject of much analysis and debate during the past decade. In all of this flurry of concern with perceived limits to growth, however, insufficient attention has been accorded to the effects of a variable that may overshadow all of the rest in importance: changing population dynamics and lifestyles, and their socioeconomic impacts.

Explosive population growth in the less developed countries and population stabilization in the more developed nations have created unprecedented social issues and problems. The future societal ramifications of changing age compositions, patterns of family formation and dissolution, movements from one region to another, health status and demands for care, and participation in the labor force will be profound.

This paper focuses on the linkage of several elements of demographic change that usually are modeled separately. To our knowledge, it is the first multistate population projection that contains not only fertility, mortality, and migration schedules, but also considers marriage and divorce patterns and includes a two-sex model that ensures consistency in the determination of the future number of transitions between the married, divorced, and widowed states.

A list of related publications appears at the end of this paper.

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ABSTRACT

This paper outlines a theoretical framework for the consistent and policy relevant projection of populations disaggregated by sex, age, marital status, and region. The framework makes use of multistate life table and projection techniques, and a two-sex model of transitions between the married, divorced, and widowed states, to ensure the consistent determination of the future size and structure of the population on the basis of transitions assumed to occur over the projection period. It also uses model schedules to reduce the information load required for projection and to produce descriptive and interpretable parameters which can be explained and projected with the aid of an economic model that relates these parameters of demographic transition to their demographic and economic determinants. An illustrative application of this framework, using Australian data, is included.

CONTENTS

A FRAMEWORK FOR MULTISTATE DEMOECONOMIC MODELING AND PROJECTION, WITH AN ILLUSTRATIVE APPLICATION

1. INTRODUCTION

Regional population projections assist decision makers in the analysis and formulation of a wide range of economic and population policies. These policies include the plans by government agencies for future expenditures in the areas of education, health, welfare, housing, and the provision of social infrastructure and the plans by private firms for the level and mix of output and the location of plant and equipment necessary to most efficiently and profitably meet expected future consumer demands. In the past, such projections were made using fixed or simple time-trended assumptions regarding future movements in the components of regional population change, with little attempt being made to ensure internal consistency between these assumptions, or to specify the implicit economic/demographic growth scenarios underlying them. Demographic and economic change are intricately and simultaneously linked, and the usefulness of regional population projections is enhanced if they incorporate consistently the relationships between demographic and economic variables, including those policy variables over which decision makers have control. Given the wide variety of uses and users of regional population projections, the relevance of the projections will also be increased by the maintenance of a high degree of disaggregation for important variables such as sex, age, marital status, and, where relevant, race.

In this paper, a possible framework for multistate demo-economic projection which incorporates these dimensions is presented. This framework makes use of several techniques currently available for the modeling and projection of demographic variables, including

1. *multistate mathematical demography*, which imposes standard demographic accounting identities on the projections and incorporates the impacts of preceding demographic events by allowing for simultaneous and consistent determination of the effects on the projected size and distribution of the population of all the rates of transition that are assumed to occur in the projection period;
2. *a two-sex model of marriage, divorce, and "widowing"**, which takes into account the parallel transitions among individuals of each sex and ensures that there are no inconsistencies between such transitions;
3. *model schedules*, which parsimoniously describe the age distributions of demographic transitions ensuring consistency across age distributions and reducing the information to be projected to a few descriptive and interpretable parameters for each schedule of transition; and
4. *an economic model*, which determines the projected parameters of the demographic transitions by incorporating explicitly the assumptions that are made regarding the demographic and economic environment underlying the projection, and by clearly specifying the relationships that exist between this environment and population change.

This framework ensures that population projections will be disaggregated, consistent, and policy relevant. At this stage, however, the framework considers only one side of the joint interaction between the demography and economy of regions--the effect of economic change upon regional populations and their distribution--but in a more comprehensive manner than is normally provided within studies of joint interactions between economic and population growth. Population change, via its impact on

*By "widowing" we mean the transition from the married to the widowed state.

consumer demand, housing demand, and labor supply, will affect the economic environment of regions, which will simultaneously affect the various components of that population growth. The framework presented here could readily be incorporated into a wider model of simultaneously determined economic and demographic growth [see Powell (1982) for a prototype of such a model for Australia, and Ledent (1978) for a model of Tucson, Arizona].

This paper represents a joint effort between two research groups that have been closely involved in the development of these techniques. The International Institute for Applied Systems Analysis (IIASA) has played a significant role in the development of the techniques and applications of multistate demography (Rogers 1980, 1981) and in the estimation of model schedules of many facets of demographic behavior for a large number of countries (Rogers and Castro 1981a). The IMPACT Project, in its efforts to construct a set of economy-wide models that will provide a systematic framework for the analysis of a large number of policy issues, has developed a facility for the consistent projection of the Australian population disaggregated by age, sex, and marital status (Sams 1979a; Sams and Williams 1980, 1982; Williams 1981). This facility employs model schedules and a two-sex marriage and divorce model and is driven by an economic model that relates marriage, divorce, fertility, and female labor force participation behavior to their economic determinants.

The framework described here combines aspects of these developments in demographic techniques at IIASA and IMPACT and is more fully described in the following section. To give an example of the application of this framework, a projection of the level and age/sex/marital status/regional distribution of a population under the influence of regionally differentiated economic growth is made in Section 3. This projection is based on Australian data but a substantial proportion of the data were not readily available and were approximated, and the full framework could not be implemented in the time available. The projection, therefore, is intended only to be illustrative.

2. A FRAMEWORK FOR MULTISTATE POPULATION PROJECTIONS

A schematic representation of the proposed framework for the consistent projection of a population disaggregated by age, sex, marital status, and region of residence is given in Figure 1. For simplicity of representation, only two regions, A and B, are assumed to exist. We consider each of the features of this framework in turn.

2.1 The Projection Algorithm

Multistate population projection techniques are used to simultaneously determine the projected population from its sex/age/marital status/region-specific flows of migration, marital status changes (becoming married, divorced, remarried, and widowed), deaths and fertility.* For each year of projection, transition probabilities calculated from multistate life tables generated separately for each sex may be used to determine the projected level and distribution of the population. The projected populations can then be augmented by the expected numbers of international migrant arrivals and departures (disaggregated by sex, age, marital status, and region of arrival or departure) to give the projection of male and female populations by age, marital status, and region of residence.

These projections are consistent in the sense that the assumed transitions are used to determine the population, one sex at a time. However, the concept of consistency also relates to the harmony between the assumed demographic transitions themselves. For example,

1. research suggests that families tend to migrate together, thus the probability that a child will migrate should be consistent with the probability that persons of the age of his or her parents will migrate;

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*The following references may be consulted for a discussion of multistate population projection techniques: Rogers (1980, 1981).

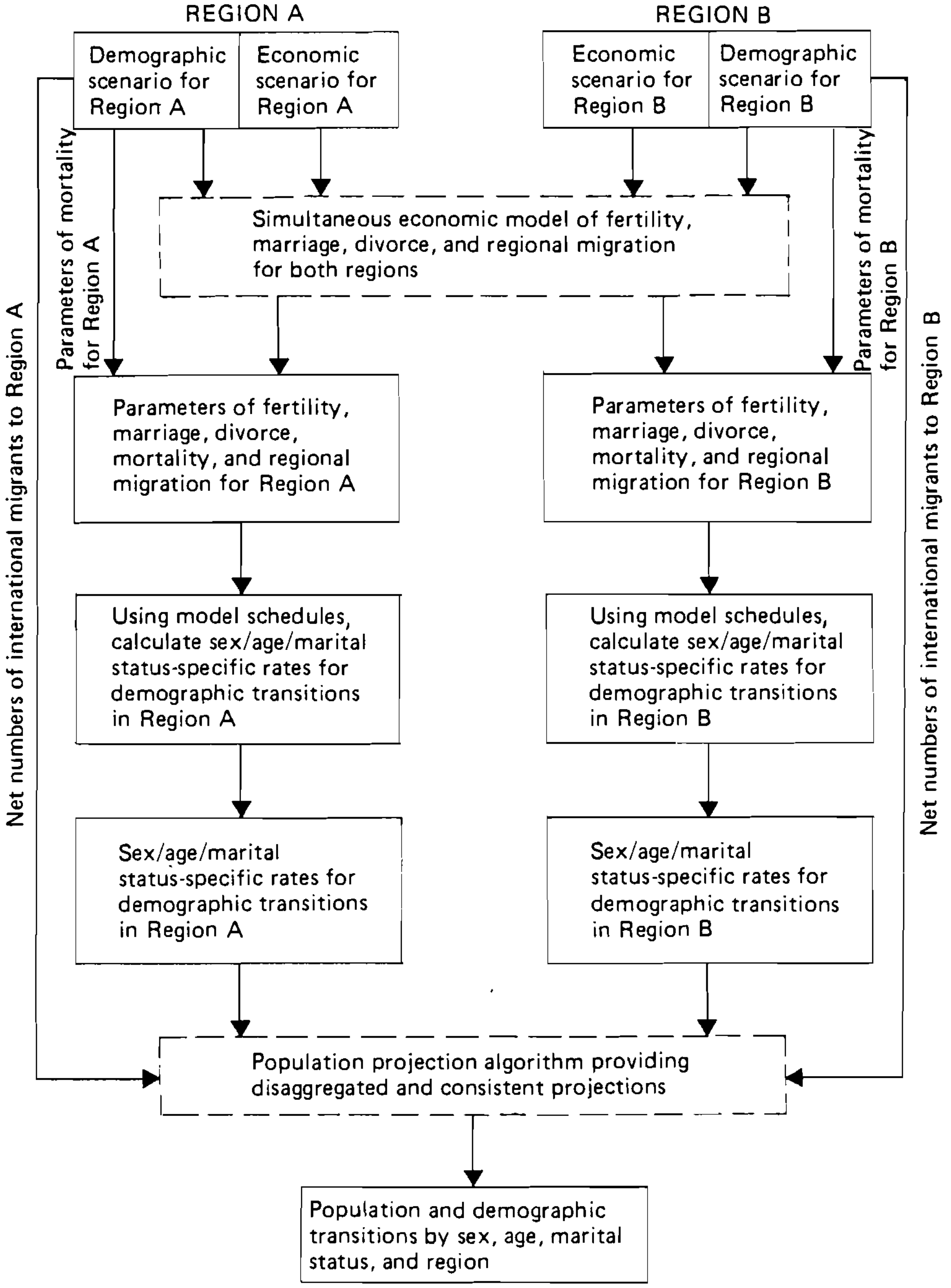

Figure 1. Schematic representation of a proposed framework for the consistent projection of a population disaggregated by age, sex, marital status, and region of residence.

2. the likelihood of a woman giving birth is higher when she is married and in the prime childbearing ages, and also reflects the number of children she has already borne and expects to bear in the future, thus fertility projections should be consistent with these characteristics of the female population; and

3. at various times, usually as the result of large scale migration or of war, the number of men and women of prime marriageable ages can become seriously unbalanced, thus it is necessary to ensure that the marriages of men (women) are consistent with their likelihood of finding a suitable partner.

Normally these consistencies can be approximated by the thoughtful projection of the required flows. In our framework, this is achieved partly by the use of model schedules to ensure consistency across age distributions, and partly by the use of an economic model to simultaneously estimate the important features of demographic flows on the basis of their economic and demographic determinants. Consistency in the marital status change behavior of males and females requires special treatment. As with most population projection facilities in the demographic literature, with the exception of the IMPACT facility, the multistate projection facility deals only with a single sex at a time. Especially in the case where the marital status structure of the population is being considered, it is not realistic to project the transitions among individuals of one sex without taking into account parallel transitions among individuals of the other sex. The separate projection of the evolution of the male and female populations in our framework could lead to inconsistencies, such as the number of marriages or divorces of males not coinciding with the number of marriages or divorces of females over a given period, and the number of new widows during the year not coinciding with the number of deaths among married men in that year, and so on.

Operational resolutions to the problem of two-sex interaction are few; this paper adopts one proposed by Sams (1981a) and incorporated into the population projection algorithm developed at IMPACT. The Sams procedure rests upon a matrix of married couples disaggregated by the age of each partner, which is updated from year to year over the projection period. The updating of this matrix requires the establishment of four sets of consistent demographic flows disaggregated by the age of the male and the age of the female involved in the transition--becoming married, divorced, and widowed, and migrant arrivals and departures (both regional and international) of married persons. In general, these consistent cross-tabulated flows are established by a two-stage process. First, the number of marriages, divorces, deaths, and migrant arrivals and departures of married persons are calculated at each age for each sex, on the basis of projected model schedules and the at-risk population for each event. Second, the consistent cross-tabulations by the age of each party to the event are established, sometimes leading to the adjustment of the initial numbers of marriages, etc., for each sex and, consequently, to changes in the implied age-specific rates.

For marriages, the Sams approach makes use of the possible difference between the number of marriages to men (women) of a given age *desired* by women (men) of that or some other age, *independent* of the supply of men (women) available, and the number of marriages which actually take place. This divergence may occur for either or both of two reasons: there are physically not enough eligible men (women) of that given age available for marriage or the desires of eligible men (women) of that age are such that they do not wish to marry women (men) of the other age. The numbers of men and of women at each age desiring to marry are determined from model schedules of desired marriage and an economic model which projects, among other things, the parameters of those model schedules. We assume that these model schedules (in fact gamma distributions) for each sex are the marginal distributions of a bivariate gamma function, whose parameters are those of the model schedules for males and females plus a correlation coefficient which can be estimated from cross-tabulated data. From this bivariate distribution it is possible to determine the numbers of marriages of couples of given ages desired by men and desired by women.

We then set up a constrained minimization problem which minimizes the differences between desired and actual marriages of men and women at each pair of ages, subject to the constraints that the number of marriages between women and men of any ages be not less than zero and that the total number of marriages of all women (men) to men (women) of a particular age does not exceed the stock of men (women) of that age. It is possible that not all of the total stock of men or women of a given age eligible for marriage would be willing to marry; in such cases, we could assume that only a proportion of the supply of women (men) of that particular age would be available for marriage. Such proportions would need to be determined by observation and intuition, since there would be little information available to estimate them systematically. Now, if none of these constraints were binding the numbers of marriages between men and women of given ages would be simply the weighted sum of the number of marriages for couples of these given ages desired by men and desired by women. The weights could be expected to be equal, except in cases where the desires of one sex were found to be dominant. In such cases, the weights for the other sex could be set to lower values, even as low as zero. In situations where the constraints are binding, it is possible to establish a linear programming technique to determine consistency between the marriages of males and females at each pair of ages, as explained in Sams (1981a). Once the number of marriages by the age of each spouse is determined, consistency-adjusted age-specific marriage rates for men and women can be calculated using the populations at risk.

So far, we have ignored the complication that there are three types of marriages, depending on previous marital status, for each sex, and therefore nine combinations of marriages between the sexes. In fact, the numbers of men and women at each age desiring to marry are determined separately for each previous marital status, and these are added together for each sex to form the desired level of marriage by the age of the partners. Once the reconciled cross-tabulation of marriages by the age of the partners is established, the number of marriages at each age for each sex by previous marital status is derived by distributing the reconciled number of marriages at each age in proportion to the original desired distribution of marriages by previous marital status at that age. Details of this procedure can be found in Sams (1981a).

Consistent cross-tabulations of transitions into the divorced and widowed states by the age of each spouse are calculated on the basis of a matrix of married couples by age of wife and age of husband. It is assumed, quite plausibly, that the death of a married male (female) is independent of the age of his (her) wife (husband). Thus, the widowing of married females (males) of a given age are equal to the number of those females (males) married to males (females) of any given age multiplied by the death rates of those males (females). For divorces, as for marriages, the numbers of married men and women at each age desiring to divorce are determined from model schedules and an economic model that projects the parameters of these model schedules. The number of divorces of married couples is then determined by the matrix of married couples by age and the arithmetic average of the desired divorce rates for each partner at their given ages. A scaling factor may also be introduced to take account of the higher probability of divorce for couples with wider age differences [as suggested by several studies, including Day (1963)]. Consistency adjusted age-specific divorce rates for men and women can then be calculated using the populations "at risk". Finally, consistency must be imposed on the arrivals and departures of married male and female migrants, both regional and international. In general, this is achieved by the iterative adjustment of a standard matrix of the relative ages of migrant couples to agree with the age profiles of migrants of each sex.

Procedurally, two-sex consistency must be incorporated into the multistate projection algorithm in an iterative manner. First, the desired number of marriages and divorces must be determined from the model schedules and the populations at risk and the numbers of new widows from the couples matrix and the death rates of married persons. Two-sex consistency is then imposed upon these marital status changes. Although consistency is imposed separately for each region, this may be inadequate when the regions under consideration have substantial demographic interaction, particularly where marriages occur between persons initially residing in different regions. In such cases, the reconciliation process which adjusts desired marriage rates should incorporate the possibility that some of those desiring marriage, but unable to find a suitable partner in their region of residence, may find a partner in another region. Once two-sex consistency has been imposed, the consistency-adjusted rates of marital status change can then be used within the multistate projection algorithm to determine consistent population projections. At the same time, the stocks of married couples by age of husband and age of wife must be updated in each period according to the transitions occurring to married persons.

2.2 The Model Schedules

The basic starting measure for most demographic analyses is a central rate that is defined for a population in a given region during a particular time span. In our projection framework, these occurrence/exposure rates are used wherever possible, as the projection of rates allows for the automatic response of projected demographic transitions to changes in the age and marital status profile of the regional populations. As indicated by Figure 1, the ultimate inputs to the projection algorithm for each region are fertility rates, death rates, marriage and divorce rates, and regional migration rates. The use of occurrence/exposure rates is less valid for international migration, where the region of origin is "the rest of the world".

The use of parametric functions to smooth and describe parsimoniously sets of age-specific rates is a common practice in demography. A variety of mathematical formulas have been proposed and fitted to mortality, fertility, marriage, divorce, and migration schedules and the results have been widely used for such applications as data smoothing to eliminate irregularities, interpolating rates given for five-year age groups to single years of age, comparing different growth regimes, inferring rates from partial or inaccurate data, and forecasting future populations. The relevant literature is vast and entry into it can be made from such representative publications as Brass (1971), Coale and Demeny (1966), Coale and Trussell (1974), Heligman and Pollard (1979), Hoem et al. (1981), Rogers and Castro (1981a, 1981b), Rogers, Raquillet, and Castro (1978), United Nations (1967), and Williams (1981).

In our population projection framework, the role of model schedules is two-fold. *First*, if highly disaggregated population projections are to be made, the transitions between states of existence, or the vital flows, in each year must retain a similar degree of disaggregation. Model schedules allow us to condense this enormous amount of information into a few parameters for each transition in each year. *Second*, if the model schedules are chosen wisely, they provide a manageable number of interpretable descriptive statistics, for each demographic transition in each year, the time series of which can capture changes in the underlying determinants of that demographic transition and thereby provide the basis for econometric estimation. The model schedules chosen will vary according to the transitions under analysis and the population under consideration; the criteria for such choice should emphasize the interpretability of the parameters, their success in characterizing the important features of demographic behavior and the goodness-of-fit of the schedules to available data.

We propose the use of model schedules to characterize, in each year of projection, the age distributions of all the necessary demographic transitions:

1. fertility rates by the age and marital status of the mother for each region;
2. rates of first marriage, divorce, remarriage of divorcees, and remarriage of widows by sex and age for each region;
3. death rates by sex, age, and marital status for each region; and
4. rates of regional migrant outflows by sex, age, and marital status for each region;

with the exception of:

a. widowing (the remaining marital status change) by sex and age for each region, which can be determined by the stock of married couples by age of spouse and the deaths of married persons; and

b. international migrant arrivals and departures by sex, age, and marital status for each region, which, particularly in the case of arrivals, are more difficult to express in terms of occurrence/exposure rates--the normal data base for model schedules.

In the remainder of this subsection, we detail the model schedules that have been chosen for our illustrative projection in Section 3, and refer readers to the references listed above for model schedules that have been applied in the demographic literature.

2.2.1 Fertility

The demographic literature has concentrated on the modeling and projection of age specific fertility rates of all women of childbearing age. However, our framework allows us to consider separately marital and nonmarital fertility rates, thus enabling us to capture the effects on fertility of changes in the age and marital status distributions of women and to consider the different economic and demographic influences on marital and nonmarital fertility. In the illustrative projection given in this paper, a double-exponential function [developed and used by Coale and McNeil (1972) for first marriages] was used to describe, separately for women of each marital status in each region, fertility rates at age x:

$$f(x) = gae^{-\alpha(x-\mu) - e^{-\lambda(x-\mu)}} \qquad (1)$$

where the shape of the curve is defined by three parameters, α, μ, and λ, and the level of the curve is defined by a, the scaling parameter, and g, the gross fertility rate, which is the sum of the age-specific fertility rates. Although these parameters (apart from g) are not easily interpretable, it is possible to derive the propensity, mean, variance, and mode of the double-exponential function in terms of them (Coale and McNeil 1972; Rogers and Castro 1981a; and Sams 1981b). We are thus able to identify four potentially estimable parameters of marital and of nonmarital fertility--the propensity to have a confinement, and the mean age, variance in age, and modal age of women having confinements.*

However, it is with some reservations that we have adopted this approach. Certainly the numbers and age distributions of married and unmarried women of childbearing age should influence fertility, and analysis of movements over time in the parameters of these model schedules of fertility would shed some light on past and expected future fertility behavior. This approach may be adequate in the case of nonmarital fertility, but for marital fertility the decision to have a child is also strongly influenced by the number and timing of previous children born to the mother. This aspect of marital fertility could be incorporated via the use of separate model schedules for the age distributions of the fertility rates of women having confinements of different birth orders. Analysis of the changes over time in the parameters of these age and birth order-specific model schedules would give insights into the influences on marital fertility of the past experiences of the cohorts of women of childbearing age and of the decisions made by parents with respect to family size. A time series of such parameters would provide an excellent basis for economic modeling.

2.2.2 *Marital Status*

Although Coale and McNeil's (1972) double-exponential model schedule of first marriage rates was introduced a decade ago, parametrized schedules of other changes in marital status have been produced only recently. Williams (1981) fitted gamma distributions to Australian rates of first marriage, divorce,

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*The use of confinements, as opposed to births, appears appropriate since women do not make the decision to have a multiple birth.

remarriage of divorcees, and remarriage of widows, for each year from 1921 to 1976. Using the gamma distribution, the rate of first marriage, of divorce, or of remarriage for males or females of age x is given by:

$$p(x) = P \left\{ \frac{1}{\beta^{\alpha}\Gamma(\alpha)} (x - x_0)^{\alpha} e^{-(x-x_0)\beta} \right\} \qquad (2)$$

where

P — is an index of the propensity to first marry, to divorce or to remarry;

α and β — are the parameters of the gamma distribution which can be expressed in terms of the mean age and variance in age of first marriage, of divorce, or of remarriage;

x_0 — is exogenously set equal to the last age at which a zero rate occurs; and

Γ — is the gamma function.

Thus the distribution across ages of age-specific rates of each marital status change can be expressed in terms of three easily interpretable parameters--the propensity, mean age, and variance in age--whose time series can then be modeled and projected using an economic model.

These model schedules provided adequate descriptions of Australian marital status changes, although some difficulties arose with age distributions that exhibited steep rises in early ages: in particular, the age distributions of first marriages. This difficulty was overcome by the addition of a second, time-invariant, gamma distribution. Functions based on the Coale-McNeil double exponential distribution seem better able to cope with the problem of steeply rising age distributions than the gamma distribution. Although the parameters of both functions can be expressed in terms of a propensity, mean age, and variance in age, the double-exponential function requires a further parameter--the modal age--whose movements over time may be more difficult to model and project. In the specification of model schedules, some sacrifice in accuracy across the age distribution may be necessary in order to allow for improved modeling and projection of movement over time in the schedule. For this reason, gamma schedules have been used in the illustrative application in this paper.

2.2.3 Mortality

Three principal approaches have been advanced for summarizing age patterns of mortality: *functional descriptions* in the form of mathematical expressions with a few parameters (Benjamin and Pollard 1980), *numerical tabulations* generated from statistical summaries of large data sets (Coale and Demeny 1966), and *relational procedures* associating observed patterns with those found in a standard schedule (Brass 1971). Until very recently, the search for a "mathematical law" of mortality produced mathematical functions that were successful in capturing empirical regularities in only parts of the age range, and numerical tabulations have proved to be somewhat cumbersome and inflexible for applied analysis. Consequently, the relational methods first proposed by William Brass have become widely adopted. With two parameters and a standard life table, it has become possible to describe and analyze a large variety of mortality regimes parsimoniously.

Recently Heligman and Pollard (1979) published a paper setting out several mathematical functions that appear to provide satisfactory representations of a wide range of age patterns of mortality. We adopt, in the illustrative projection given in this paper, the slightly modified Heligman and Pollard formula suggested by Brooks et al. (1980):

$$d(x) = d_I(x) + d_A(x) + d_S(x) \qquad \text{for } x = 0,1,\ldots,100+ \tag{3}$$

where

$$d_I(x) = \begin{cases} Q_0 & \text{for } x = 0 \\ Q_1^{x^\gamma} & \text{for } x > 0 \end{cases}$$

$$d_A(x) = Q_A \, e^{-\left(\frac{\ln x - \ln X_A}{\sigma}\right)^2} \qquad \text{for } x \geq 0$$

and

$$d_S(x) = Q_S \frac{e^{x/X_S}}{1 + Q_S K e^{x/X_S}} \qquad \text{for } x \geq 0$$

We can interpret these three terms as representing infant and childhood mortality, mortality due to accidents, and mortality due to aging.

Death rates can be shown to differ markedly not only between ages but also between sexes, between marital states and, perhaps, between regions. At the IMPACT Project, model schedules based on Equation 3 have been successfully fitted to Australian age-specific data for the death rates of persons of each sex and marital status. In practice not all components of the Heligman-Pollard curve are used, with the first component being omitted for married males and females and divorced and widowed females, and both the first and second components being omitted for divorced and widowed males. The IMPACT study is not region-specific, but, given availability of data, such model schedules could be fitted in each region. Movements over time in the parameters of such schedules could then be analyzed and used for projection of future mortality by age, sex, marital status, and region.

2.2.4 Regional Migration

In a recent study of age patterns in migration schedules, Rogers and Castro (1981a) have shown that such patterns exhibit a profile that can be adequately described by the mathematical expression:

$$m(x) = a_1 e^{-\alpha_1 x} + a_2 e^{-\alpha_2 (x-\mu_2) - e^{-\lambda_2 (x-\mu_2)}} + R + c \qquad (4)$$

where

$$R = a_3 e^{-\alpha_3 (x-\mu_3) - e^{-\lambda_3 (x-\mu_3)}}$$

if the curve has a retirement peak,

$$R = a_3 e^{\alpha_3 x}$$

if the curve has an upward retirement slope, and

$$R = 0$$

if the curve has neither and is approximately horizontal at the post-labor force ages. The migration rate, therefore, depends on values taken on by 11, 9, or 7 parameters, respectively. The shape of the second term, the labor force component of the curve, is the double-exponential formula put forward by Coale and

McNeil (1972). The first term, a simple negative exponential curve, describes the migration age profile of children and adolescents. Finally, the post-labor force component is a constant, another double-exponential, or an upward sloping positive exponential.

In our framework, it is necessary to determine model migration schedules for the age distributions of regional migrant outflows for each sex and marital status. The model schedule given in Equation 4 can be used, but for the married and previously married states, it is not necessary to include the first terms, since children and young adolescents do not enter these marital states. The schedule has been found to be flexible enough to adequately fit age-specific migration rates disaggregated by sex and marital status, and it has been used in the illustrative projection reported in Section 3. However, Rogers and Castro (1981b) have shown that model migration schedules can also be applied to migration flows disaggregated by the cause of movement. Similar to the birth order-specific fertility schedules discussed earlier, cause-specific model schedules of rates of migrant outflow could provide sets of parameters which more adequately capture the underlying determinants of migration and which can be more successfully integrated into an economic model of migration behavior.

2.3 The Economic Model

To produce population projections, some assumptions must be made about the transitions expected to occur over each year of the projection or, as in our framework, about the parameters of those transitions. In our framework, future movements in demographic variables are related to changes in the economic and social structure of the region under analysis. Marriage and divorce are affected, for example, by changing incomes, relative wages, unemployment, and contraceptive usage. Fertility is also affected by these factors and by the changing patterns of marriage and divorce. Movement between regions is closely tied to economic developments within those regions inasmuch as people will move to regions with higher incomes, better employment opportunities, and better housing, as well as for personal reasons, such as marriage and divorce. International migration is also a response to relative economic opportunities. Policy analysis will be greatly aided if the relationships between demographic, economic, and social variables, some of which are amenable to policy control, are explicitly incorporated into population projections.

In this section, we consider the features of an economic model which could be used to simultaneously determine the future time paths of the parameters of fertility, marriage, divorce, and regional migration on the basis of scenarios of the future economic and demographic environment. In our framework, future values of the parameters of mortality and the net numbers of international migrants are assumed to be specified exogenously. Patterns of mortality are undoubtedly related to the economic environment and, for example, to changes in the provision of health care services. If the exogenous specification of future mortality were considered inadequate (for instance, in the case of population projections for a developing country), the relationship between economic variables and the parameters of mortality could be directly specified and incorporated in the economic model. The endogenization of mortality has not been attempted here, but there are several examples of this within demoeconomic models of developing countries (Food and Agriculture Organization 1976; Rodgers, Hopkins, and Wéry 1976; Simon 1976). Future international migration will also be related to relative changes in the economic climates of origin and destination countries, as well as to changes in costs of migration and in government policies towards migration. Although no attempt has been made to endogenize international migration in this framework, there are several examples of such modeling attempts; for instance, Kelley (1965), Kelley and Schmidt (1979), Pope (1976), Quigley (1972), Wadensjö (1977), and Wilkinson (1970).

In this paper we do not fully specify a simultaneous model of fertility, marriage, divorce, and regional migration but draw upon models already developed and attempt to identify their important features and provide suggestions for a possible model.

Specifically, we draw upon work done at the IMPACT Project in specifying a simultaneous model of fertility, marriage, divorce, and labor force participation and consider how this model could be linked with models of regional migration developed elsewhere [for example, those developed at IIASA by Kelley and Williamson (1980), and Gordon and Ledent (1981)]. *First*, we will discuss the theoretical basis for, and the empirical specification of, the IMPACT model. *Second*, we will provide a brief survey of migration models, and, *finally*, we will consider how these could be combined to provide a simultaneous model of fertility, marriage, divorce, and regional migration.

*2.3.1 Fertility, Marriage, Divorce, and Labor Force Participation**

The IMPACT economic model (Brooks, Sams, and Williams 1982; Filmer and Silberberg 1977) incorporates the essential features of the "new home economics", which is an extension of consumer theory to incorporate nonpecuniary aspects of consumption, such as the utility derived from children and from leisure (see Becker 1960, 1965; Lancaster 1966; Willis 1974). The individual or the family is treated as a decision-making unit that maximizes its utility from the consumption of "household commodities", which are produced by the household using its scarce resources of goods and services purchased in the market and of time of the individual or family members. Although children are not purchased in the market, inputs of market goods and services, and of time, are used by the household to "produce" child services, which is a function both of the number of children and the resources (including time) intensity or "quality" of these children. Children therefore have a shadow price, partly reflecting the time intensity of their production and the opportunity cost of that time. Thus, with regard to fertility, the family is faced with a decision concerning the allocation of its resources of time, especially of the mother, between child-rearing, labor force participation, and leisure. If child services are "normal goods", an increase in family income will tend to increase consumption of child services, which can imply growth in the number of children and/or in expenditures per child (that is, child quality). But, if the increase in family income derives

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*This section borrows heavily from Brooks, Sams, and Williams (1982).

from an increase in the female wage rate, the shadow price of the mother's time will have increased, implying that a larger part of the increase in child services will be directed towards increased child quality, rather than increased numbers of children (Butz and Ward 1979; Heckman 1974; Mincer 1963). The effect of fertility on noneconomic variables, such as birth control and infant mortality rates, can be incorporated via their effect on the relative prices of the number and quality of children.

The "new home economics" approach has also been applied to explain marriage (Becker 1974) and divorce (Becker, Landes, and Michael 1977; Hutchens 1979) behavior. People are assumed to marry when both parties expect to enjoy a level of utility which is greater than that which they could receive if they remained single. Gains from marriage are related to the complementarity between the inputs to the household of the husband and wife, which is higher for large relative wage differentials between men and women. Since children provide an important source of utility to their parents, the demand for child services, and the complementarity of males and females in producing these child services, will act as an incentive to marry and to remain married. However, the decision to marry is not without cost, since a single person must spend resources searching for a spouse. Thus the decision to marry, the timing of that decision and the duration of search will depend not only on the gains of marriage but also on the costs of search (Keeley 1977, 1979). Since divorce and separation are the result of conscious choice on the part of at least one spouse to terminate the marriage, the reverse of the factors discussed above are assumed to apply.

The "new home economics" also provides a consistent framework for dealing with female labor force participation and its relationship to the female wage rate, the level of male earnings, and the fertility decisions of married women. The fertility decisions of earlier periods and the desired levels of child quality can influence the level of participation in the workforce, and in particular, rising levels of child quality can act as an inducement for married women to enter the workforce in order to supplement the family income.

The IMPACT economic model provides a practical application of these theories and also attempts to capture some of the dynamic elements of family formation, family size, and labor force participation and their interactions. It explains the probabilities of marriage and divorce and their age profiles (that is, in our framework, the parameters of the model schedules of first marriage, remarriage, and divorce) as a function of variables such as the demand for child services (for marriage only), the female/male relative wage rate, real GDP per capita, an index of female educational attainment (for marriage only), the rate of oral contraceptive usage (for marriage only), the number of dependents per married female (for divorce only), real social security payments (for divorce only) and dummy variables to account for the effects of war (for marriage only) and divorce legislation (for divorce only). In the model, marital confinements by birth order are determined by treating fertility decisions sequentially, beginning with the decision to have a first marital confinement and then to have higher order confinements (Sams 1979a, 1979b). First and higher order marital confinements (specifically, the crude first marital confinement rate and the mean and variance of implied completed family size) are related to the real female hourly wage rate, real GDP per capita, the rate of oral contraceptive usage, the real old age pension rate, weighted first marriages per married female (for first marital confinements only) and dummy variables to account for the effects of war. Although labor force participation rates are not directly relevant in our one-sided framework for regional population projections, the IMPACT model of labor force participation rates (Brooks, Sams, Williams 1982) could provide an important link in a fully simultaneous model of demographic-economic interactions (see Ledent 1978, Ledent and Gordon 1981 on this point).

The IMPACT economic model has been moderately successful in explaining Australian marriage, divorce, fertility, and labor force participation over the period 1921 to 1976 [see Brooks, Sams, and Williams (1982) for full details of the model specification, estimation, and performance]. Although the fertility equations are not directly related to the parameters of model schedules of fertility (and hence could not be used in our illustrative projection), aspects of this approach could be useful in the specification of the relationships between fertility parameters and economic and social variables (see Sams 1979b). Given this refinement, which we were unable to do in the time available, and adequate data, the model could be estimated with separate equations specified for each region and, when combined with equations specifying regional migration and its relationship to economic and demographic variables in the source and destination regions (to be discussed next), would provide the simultaneous model of fertility, marriage, divorce, and regional migration necessary to complete our framework for multistate population projection.

*2.3.2 Regional Migration**

People choose to migrate when they expect to incur some positive gain, either of a pecuniary or nonpecuniary nature, and their choice of destination will be that region in which they can expect to incur the greatest net benefit. The benefits associated with migration could include improved real income-earning potential for the migrant and/or his family, via higher wage rates, expanded and more secure employment opportunities, lower living costs, better educational facilities, less expensive housing, and greater availability and choice in housing. Non-pecuniary benefits of migration could include improved climate, better living environment, and enhanced personal relationships, where the migrant is moving to be closer to friends and family, or in response to changing marital arrangements, such as marriage, divorce, or widowhood. These benefits must be balanced against the costs of migration, which include transportation and relocation costs, costs of return trips to the home region, and the psychic costs of "taking a risk" and of moving away from family and friends.

*Greenwood (1975) provides an excellent survey of research on regional migration, and Long and Hansen (1979) provide an interesting study of the reasons for regional migration, both of which concentrate on the United States and have been referred to in the drafting of this section.

Models of migration flows between regions have attempted to encapsulate the personal motivations of migrants by incorporating variables representing regional income, employment and living environment differentials and measures of the costs, both real and psychic, as well as the uncertainty associated with migration. Early studies used regional population size as a proxy for income-earning potential and distance as a proxy for the transportation and psychic costs of migration as well as for the availability of information and the uncertainty involved in the move (Zipf 1946; Dodd 1950). Several studies improved upon the causal content of these gravity models by using indices of the relative attractiveness of regions to partition total migration into directional flows between each region (Somermeijer 1961; Lowry 1966). Lowry's model of migration inflows and outflows assumes that people migrate in search of jobs from low wage to high wage rates and from areas of labor surplus to those with labor shortages. According to this model, over time migration to areas of relative attractiveness will tend to reduce regional wage rate and labor supply imbalances and thereby reduce migration flows to those levels implied by the gravity model.

Many studies since Lowry have concentrated on improving the way in which economic variables are specified in migration models. Todaro (1969) has emphasized the role of the unemployment rate in the destination region as a proxy for the probability that the potential migrant will find employment in that region within a reasonable time. His model has been improved upon, for the special case of net rural-urban labor migration in developing countries, by Kelley and Williamson (1980) and a model incorporating features of both these studies has been suggested by Ledent and Gordon (1981). Ledent and Gordon assume that the propensity of an individual to move from one region to another depends on the relative attraction of the destination region, expressed as the percentage of the system's population living in that region, and on the earnings differentials between the regions, expressed by a quotient of the real expected wages one can expect to earn in those regions.

The regional real expected wage rate is given by the product of the average wage rate and the ratio of total employment to total labor force, deflated by a cost-of-living index adapted from Kelley and Williamson (1980).

The effect of uncertainty and lack of information on the decision to migrate has been modeled by using past migration levels as a positive determinant of current inmigration (Greenwood 1975). The more persons who have migrated from a given source region to a given destination region, the greater will be the quantity of information sent back from the destination region, and the greater will be the likelihood that friends and relatives will be present in the destination region. Past inmigration levels may also determine future outmigration, since persons who have migrated once are more likely to migrate again (Miller 1973; Greenwood 1973). As for psychic costs, Schwartz (1973) has suggested that the psychic cost of migration can be directly measured by the cost of visits necessary to negate the effect of isolation from family and friends.

The decision to migrate will also vary according to the personal characteristics of the migrant. Adults are more likely to migrate when they are young, since they are less likely to be restricted by family, career, and community responsibilities (Gallaway 1969), and they can expect a longer working life over which to realize the advantages of migration (Becker 1964). Because very young children are more likely to have young, mobile parents, migration rates will be higher for young children than for adolescents. Unmarried or previously married people are less likely to have their freedom of movement restricted by family ties. Race and economic and social class may have some influence on the likelihood of migration (Greenwood 1975). Education may increase the likelihood of migration, since education tends to increase the awareness of other localities and the availability of employment information and opportunities. It also tends to reduce the importance of tradition and family ties (Greenwood 1975).

Ideally, a model of regional migration flows should incorporate these demographic, economic, and noneconomic determinants of migration. As such it should separately model migration inflows and outflows; there is no such person as a net migrant. It should also respond to changes in the demographic profile of the region of origin, since sex, age, marital status, race, social and economic class, and educational attainment have been shown to influence the likelihood that an individual will migrate. In our framework, we apply projected sex/age/marital status-specific rates of migration outflow to the sex/age/marital status profile of the origin region, thus allowing for the automatic response of numbers of migrant outflows to changes in the demographic profiles of the regional source populations. Unfortunately, race, class, and educational characteristics of regional populations are not directly incorporated in this framework, since this would require projections of the populations disaggregated by all of these characteristics.

The sex/age/marital status-specific rates of migration outflow are projected from the parameters of model migration schedules, which can be grouped as follows:

1. those parameters which determine the level of the model schedule--a_1, a_2, a_3, and c;
2. those parameters which determine the shape of the model schedule--α_1, α_2, α_3, λ_2, and λ_3; and
3. those parameters which determine the location of the components of the model schedule--μ_2 and μ_3.

These eleven parameters are not all easy to interpret or model in terms of the economic and noneconomic determinants of migration, in particular those parameters which determine the shape and location of the model schedule. The majority of studies of regional migration have attempted to explain only gross migration levels, and the variables suggested in these studies can be used to model the "level" parameters. However, to maintain consistency across the age distribution of migration rates, it may be necessary to constrain the modeling of these parameters according to some simple empirically determined relationship.* In a model of migration levels, the determinants discussed above would vary in importance according to the level parameter being modeled. For instance, we could expect the level of retirement migration (as encapsulated by the parameter a_3) to be related more strongly to noneconomic determinants of migration, such as climate and lifestyle, than to employment factors. Thus, in comparison to the equation explaining a_2 (the level of labor force migration), the coefficients relating to noneconomic variables in the equation explaining a_3 would be *relatively* greater than those relating to economic variables. The means by which the more poorly determined "shape" and "location" parameters would be projected could vary according to the particular characteristics of the country under analysis, with some being projected exogenously on the basis of simple time trends or as functions of the level parameters (as in Schmidt 1980). For instance, the location parameters could be projected using a simple time trend reflecting, say, for μ_2, a long term decline brought about by the increased independence of young persons and, for μ_3, a long term decline brought about by the declining age at retirement. This approach has the advantage of reducing the number of parameters necessary for modeling and projection.

2.3.3. The Simultaneous Model

The above discussion has detailed the components of an economic model of fertility, marriage, divorce, and regional migration which could be incorporated into our framework for multistate population projection. Given sufficient data, the parameters of the model schedules of each of these demographic transitions, for each region, can be modeled on the basis of a number of economic and social variables which have been detailed

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*Exhaustive studies of model migration schedules in developed countries by Rogers and Castro (1981a) suggest at least the following relationship: $a_3 < a_1 < a_2$.

above. Some of these variables, such as regional wage rates and income levels, would, in conjunction with other variables, jointly determine all of the demographic transitions, whereas other variables, such as climate and relocation costs, would figure in only one of the transitions. Unfortunately, time, data, and financial constraints have not allowed us to estimate such a model as yet. Thus in the illustrative projection for Australia presented in the following section, only parts of such a model have been implemented.

3. AN ILLUSTRATIVE APPLICATION

In this section we combine the projection facilities set up by IIASA and IMPACT to produce an illustrative projection of the Australian population disaggregated by two sexes, 101 single years of age, four marital states and two regions, where Region A comprises the more populous southern states of New South Wales, Victoria, South Australia, Tasmania, and the Australian Capital Territory, and Region B comprises the sparsely populated and predominantly northern states of Queensland, Western Australia, and the Northern Territory. The IIASA and IMPACT facilities each contain some, but not all, of the features of our framework. The facility developed at IIASA employs a consistent multiregional projection algorithm, which uses model schedules and life tables but does not allow for two-sex/marital status consistency, nor does it have an economic model to drive its projections. IMPACT, on the other hand, employs an algorithm which uses model schedules, allows for two-sex/marital status consistency, and has an economic model to drive its projections, but it does not incorporate a regional dimension nor does it use life tables.

The two facilities can be combined by using a three-step procedure. First, chosen scenarios of future regional economic growth are fed into the IMPACT facility's economic model to derive projections of the parameters of marriage and divorce, which are then used with the model schedules to determine initial projections of the numbers of marriages and divorces by sex and age for each region. Consistency between the marriage and divorce behavior of males and females and between the deaths of married persons and the widowing of their spouses is then enforced separately for each of the two regions to derive consistency-adjusted projections of numbers of marriages, divorces, and widowings by sex and age in each region, which are then reconverted to rates per numbers of persons at risk for input to the IIASA facility. Second, these consistent projections of marital status flows and exogenous projections of parameters of fertility, deaths, and regional migration are then fed into the IIASA facility to determine, via model schedules, multistate life tables, and multistate projection techniques, the evolution of population disaggregated by age, sex, marital status, and region. Third, because international migration is not included in IIASA's facility, it must be added on at each iteration.

It is unfortunate that at this stage fertility and regional migration could not be determined by an economic model; however, the parametric assumptions for these two components of change have been chosen so as to produce results roughly consistent with the outputs one could expect from an economic model. Also, in general, data were not readily available at a regional level for the estimation of the model schedules. Thus, for marriage, divorce, fertility, and death rates, model schedules which had been fitted to Australia-wide data were used. The level parameters of these model schedules were then adjusted, for each region, to reproduce the numbers of marriages, divorces, births, or deaths experienced in 1980 for that region. At this point, it is important to stress again that the projection is only intended to be illustrative: data have been crudely constructed, the full framework has not been implemented and the differences between the demographic and economic scenarios in the two regions have been exaggerated, to some extent, to better illuminate features of the framework. The principal purpose of this illustrative application is to show that the framework can be implemented and that it can be a useful analytic and policy-relevant tool.

3.1 The Demographic and Economic Scenarios and Their Implications

Details of the derivation of the consistent marital status flows and of the exogenous projections of fertility, deaths, and interregional and international migration are set out in Williams (1982); they will only be briefly summarized here and presented along with their implications for the crude rates of projected demographic transitions.

3.1.1 Marital Status Flows

Lacking separate models for Region A and Region B, we have used the national economic model (Brooks, Sams, and Williams 1982) of the IMPACT facility to project parameter values for the model schedules in each region, as follows. First, a low economic growth scenario was adopted by the national model to project a time series of parameters of marriage and divorce for each sex. These were assigned to Region A. Second, a somewhat higher economic growth scenario was adopted to project the parameters for Region B. These scenarios (detailed in Sams and Williams 1982) are best characterized by the assumptions regarding per annum growth in real Gross Domestic Product per capita of (0.0%, 2.0%) and the choice of the long-term unemployment rate of (6.0%, 2.0%) for the (low, high) scenario. This procedure assumes that the elasticities of the parameters of marriage and divorce to changes in economic variables in each region are the same as for the nation as a whole--a reasonable assumption for the large regions being considered in this illustration.

According to the economic model, changes in the popularity of marriage can be attributed to the positive effects of rising demand for "child services" and rising real GDP per capita, as well as to the negative effects of movements towards equality in male and female wage rates and to the increasing level of female educational attainment. In the projection procedure, the negative influences upon marriage are equal for both regions, since the latter two variables are assumed to increase at the same rate in each region. However, compared with Region A, higher growth in real GDP and higher demand for child services is assumed in Region B. As a result, the projected parameters indicate, for males and females, a higher propensity for, and lower mean age and variance in age at, first marriage and remarriage of divorced and widowed persons in Region B than in Region A. The popularity of divorce in the economic model is positively related to growth in real GDP per capita, in the relative wage rate and in the real values of the pensions of widows, and to the decline in the number of children per married woman. Again, the more positive economic influences in Region B are such that a higher propensity to divorce and a higher mean age and variance in age at divorce are projected for Region B than for Region A. The differentials between Region A and Region B grow over the period for both marriages and divorces.

These projected parameters were used to calculate the consistency-adjusted numbers of marriages, divorces, and widowings by sex and age in each region, which were then used in the population projection. As Tables 1 and 2 indicate, the combined effect over the projection period of changes in these parameters and in the populations at risk in Region B is to increase substantially the crude first marriage and divorce rates. For Region A, however, the crude first marriage rate for both sexes declines and the crude divorce rate for both sexes increases until the early 1990s and then begins to decline such that, over the whole projection period, the rate of increase is much slower than that experienced in Region B. These different growth rates reflect the negative effect of a poor economic environment on the propensity to change marital status. The crude remarriage rates for widowed and divorced males and females also decline substantially for Region A, but the corresponding rates for Region B increase for males and decline for females, as a result of the complex interaction between changes in the age-specific rates of remarriage and changes in the age and marital status distribution of the regional populations. The crude widowhood rates in Region A increase slightly for both males and females, but in Region B the crude widowhood rates are lower and first increase and then decrease over the projection period, partly as a result of the lower crude death rates in Region B, which allow married couples to survive longer.

TABLE 1

PROJECTED CRUDE MARITAL FLOW RATES FOR MALES, 1980/81 TO 2000/01

	First Marriages		Divorces		Widowings		Remarriage Divorcees		Remarriage Widows	
	Region A	Region B	Region A	Region B	Region A	Region B	Region A	Region B	Region A	Region B
1980/81	534.8	519.2	109.1	106.8	43.3	40.2	1927.9	1905.4	222.0	221.6
1981/82	542.1	535.3	110.1	107.7	43.4	40.5	1860.7	1891.6	220.0	221.7
1982/83	544.4	547.2	134.1	119.7	43.5	40.7	1829.5	1888.1	218.1	222.2
1983/84	543.9	556.3	135.8	122.6	43.6	40.9	1810.1	1893.4	216.4	223.0
1984/85	541.7	563.5	137.8	126.1	43.6	41.1	1779.0	1896.3	214.8	224.1
1985/86	537.7	569.1	140.2	130.3	43.9	41.2	1747.1	1902.9	213.2	225.3
1986/87	534.7	575.8	143.4	135.4	44.0	41.3	1718.0	1914.1	211.6	226.6
1987/88	533.3	583.8	148.1	141.6	44.1	41.3	1693.7	1933.2	209.7	228.0
1988/89	532.2	591.9	152.7	148.0	44.2	41.3	1673.9	1958.3	207.7	229.5
1989/90	531.2	599.1	156.1	153.3	44.3	41.3	1655.3	1985.9	205.9	231.3
1990/91	529.3	605.2	158.1	157.5	44.3	41.3	1636.8	1012.8	204.0	233.2
1991/92	529.4	613.6	159.0	160.8	44.4	41.2	1620.5	2043.2	203.1	236.3
1992/93	527.1	619.7	158.6	163.5	44.5	41.1	1601.4	2071.2	201.8	239.3
1993/94	523.6	624.6	157.2	165.4	44.6	41.0	1578.4	2095.2	200.3	242.3
1994/95	519.4	629.1	155.9	167.3	44.6	40.8	1552.7	2115.8	198.8	245.4
1995/96	515.3	633.5	154.7	169.2	44.7	40.7	1526.2	2134.8	197.5	248.7
1996/97	511.5	638.3	153.7	171.2	44.8	40.5	1500.1	2153.7	196.2	252.1
1997/98	507.6	643.4	152.5	173.2	44.8	40.4	1474.5	2173.2	194.7	255.4
1998/99	504.0	649.1	151.1	175.2	44.9	40.2	1449.2	2194.2	193.0	258.5
1999/2000	500.6	655.5	149.9	177.2	44.9	40.0	1424.3	2216.8	191.3	262.2
2000/01	497.6	662.5	148.7	179.3	45.0	39.8	1399.5	2239.8	189.6	265.6
Average Annual Growth Rate (in percentages)	-0.36	1.22	1.55	2.39	0.19	-0.05	-1.60	0.80	-0.79	0.91

TABLE 2

PROJECTED CRUDE MARITAL FLOW RATES FOR FEMALES, 1980/81 TO 2000/01

	First Marriages		Divorces		Widowings		Remarriage Divorcees		Remarriage Widows	
	Region A	Region B	Region A	Region B	Region A	Region B	Region A	Region B	Region A	Region B
1980/81	730.2	753.4	109.1	106.6	107.2	100.0	1375.2	1578.3	60.8	70.8
1981/82	740.3	778.0	110.2	107.5	107.5	100.4	1320.1	1533.0	59.8	69.7
1982/83	744.5	797.2	134.2	119.5	107.8	100.7	1290.4	1499.1	58.7	68.6
1983/84	745.1	811.1	135.8	122.5	108.2	100.9	1271.3	1474.4	57.6	67.5
1984/85	741.8	821.6	137.9	126.0	108.6	100.9	1242.9	1449.7	56.5	66.6
1985/86	734.7	829.3	140.2	130.3	109.1	100.9	1213.1	1429.5	55.5	65.8
1986/87	729.1	838.4	143.4	135.4	109.3	100.7	1184.9	1416.2	54.5	65.0
1987/88	727.4	852.0	148.0	141.6	109.5	100.5	1160.3	1407.6	53.5	64.2
1988/89	727.5	867.6	152.7	148.1	109.7	100.2	1139.8	1405.2	52.5	63.5
1989/90	727.3	882.9	156.1	153.0	109.9	99.8	1121.4	1406.4	51.5	62.9
1990/91	726.7	897.2	158.2	157.5	110.0	99.4	1103.0	1408.0	50.7	62.4
1991/92	728.9	915.4	159.0	160.8	110.1	98.9	1088.4	1414.7	49.8	61.9
1992/93	727.3	930.7	158.6	163.3	110.1	98.4	1071.7	1420.1	48.9	61.4
1993/94	723.4	944.2	157.3	165.2	110.1	97.9	1052.7	1424.0	48.0	61.0
1994/95	718.0	956.3	156.0	167.0	110.1	97.3	1032.2	1426.9	47.1	60.6
1995/96	712.3	967.8	154.8	168.8	110.1	96.8	1011.5	1429.9	46.4	60.3
1996/97	706.9	979.6	153.9	170.7	110.1	96.2	991.0	1433.6	45.6	60.1
1997/98	701.2	991.9	152.7	172.6	110.1	95.6	971.1	1438.4	44.9	59.9
1998/99	695.5	1004.6	151.4	174.5	110.1	95.0	951.5	1446.1	44.1	59.7
1999/2000	690.1	1017.7	150.1	176.4	110.0	94.4	932.3	1457.6	43.4	59.6
2000/01	684.8	1031.2	149.0	178.4	109.9	93.8	913.9	1470.2	42.8	59.6
Average Annual Growth Rate (in percentages)	-0.32	1.57	1.56	2.57	0.12	-0.32	-2.04	-0.35	-1.76	-0.86

3.1.2 Fertility

Fertility rates by the age, marital status, and region of the mother were based on model schedules of the age distribution of age-specific fertility rates. Model schedules were fitted to Australia-wide data for the fertility rates of married and unmarried mothers, and it was assumed that the same model schedules, with the same parameter values, would pertain in each region, except that the gross fertility rates would vary between regions over the projection period.* Gross fertility rates for marital births were assumed to increase by 0.6% per annum in Region A and by 0.5% per annum in Region B, implying that the net effect of economic growth is to reduce fertility. For nonmarital fertility, the gross fertility rates were assumed to increase faster than those for marital fertility, at 0.65% per annum in Region A and 0.55% per annum in Region B. Given the assumptions of high levels of adult international migration and of declining death rates, these slow increases in fertility do not counteract the aging of the population in either region. In Region B, fertility is assumed to increase more slowly than in Region A but the projection of higher marriage rates in Region B leads to a higher proportion of women in the region being exposed to the higher fertility rates of married women (compared with unmarried women). Consequently, as shown in Table 3, the crude birth rate in Region B increases by an average of 0.24% per annum, whereas that in Region A declines by 0.17% per annum. The net reproduction rate (which removes the influence of changing age distributions of women over time and between regions) increases in Region A by 0.50% per annum and rises in Region B by 0.86% per annum, such that, by the year 2000 the net reproduction rate in Region A is 1.0132 and in Region B is 1.1196, compared with 0.9161 and 0.9442, respectively, in 1980.

*Model schedules (as described in Section 2) were fitted to data on confinement rates of married and unmarried mothers, under the assumption that the schedules for unmarried women would provide rates which could be applied to the population of women in each nonmarried state. The number of confinements so derived were multiplied by a factor of 1.010 to allow for multiple births and a sex ratio of 0.513 was applied to derive the total numbers of male and female births.

TABLE 3

SUMMARY STATISTICS FOR PROJECTED DEMOGRAPHIC TRANSITIONS, 1980/81 TO 2000/01

	Crude Birth Rates		Crude Death Rates		Crude Migration Rates	
	Region A	Region B	Region A	Region B	Region A	Region B
1980/81	15.3	16.1	75.4	68.1	24.6	143.6
1981/82	15.3	16.0	75.5	68.1	24.1	144.2
1982/83	15.3	16.0	75.6	68.1	23.7	145.0
1983/84	15.3	16.0	75.8	68.1	23.2	145.4
1984/85	15.3	16.1	76.0	68.1	22.7	146.2
1985/86	15.4	16.2	76.1	68.0	22.3	146.9
1986/87	15.4	16.3	76.3	68.0	21.9	147.2
1987/88	15.5	16.4	16.5	67.9	21.3	147.8
1988/89	15.5	16.5	76.7	67.8	20.8	148.3
1989/90	15.5	16.7	76.9	67.7	20.4	148.8
1990/91	15.5	16.7	77.0	67.6	19.9	149.4
1991/92	15.5	16.8	77.2	67.4	19.3	149.9
1992/93	15.5	16.8	77.3	67.2	18.8	150.3
1993/94	15.4	16.9	77.5	67.0	18.3	150.7
1994/95	15.4	16.9	77.6	66.8	17.8	151.2
1995/96	15.3	16.9	77.7	66.5	17.3	151.5
1996/97	15.2	16.9	77.8	66.3	16.8	152.0
1997/98	15.1	16.9	77.9	66.0	16.2	152.3
1998/99	15.0	16.8	78.1	65.7	15.7	152.6
1999/2000	14.9	16.8	78.2	65.4	15.1	152.8
2000/01	14.8	16.9	78.3	65.0	14.5	153.5
Average Annual Growth Rate (in percentages)	-0.167	0.242	0.189	-0.232	-2.642	0.333

3.1.3 Mortality

Death rates by sex, age, marital status, and region were also based on model schedules, which were fitted to Australia-wide data for age-specific death rates of persons of each sex and marital status. It was assumed that the same model schedules, with the same parameter values, except for the level parameters, would pertain in each region. The parameters were held constant over the projection period, with the exception that the level parameters were assumed to decline by 1.5% per annum to the year 2000, implying an equivalent decline in the age-specific death rate for all ages. However, the crude death rate, shown in Table 3, increases by an average of 0.19% per annum for Region A and declines by only 0.23% per annum for Region B; this is a result of the increased concentration of the population in older age groups, especially in Region A with its lower overall fertility and higher outmigration.

3.1.4 Regional Migration

Model schedules were fitted to age-specific rates of migration outflow for each sex, marital status, and region. Unfortunately, it was not possible to use these model schedules beyond the first year of projection.* Instead, the *numbers* of migrants implied by the model schedules in that first year were used for the remainder of the projection period, with those numbers being scaled uniformly in each year to ensure a total net migration towards Region B of 55,000 persons by the year 2000--an annual average growth of 2.5%. Thus, although migration from Region B to Region A is assumed to grow at 2.0% per annum, the greater economic growth and improved employment opportunities

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*Since the IMPACT facility is not constructed on a regional basis, it was necessary to implement that facility separately for each region. Thus in a projection for Region A the facility has no knowledge about the population of Region B, and therefore cannot use migration inflows expressed in terms of rates of migration per demographic group in Region B. This is an unfortunate situation which could not be remedied in the time available.

in Region B are assumed to induce migration from Region A to Region B to grow at an average of 2.2% per annum. The consequences of these assumptions will be discussed along with those for international migration.

3.1.5 International Migration

The exogenous projections of net numbers of international migrants were based on the assumptions that, for Region A, total net international migration would increase at approximately the same rate as population growth such that it equalled about 0.55% of the population of Region A throughout the projected period, and, for Region B, total net international migration would increase faster than population growth such that it increased from 0.53% of the population of Region B in 1980 to about 0.60% in 2000. These assumptions imply an annual average increase of 1.04% for Region A and 3.35% for the high growth region, Region B, culminating in a net international migration of 74,500 persons to the more populous Region A and 37,500 persons to Region B in the year 2000. The same sex/age/marital status distribution of arrivals and departures for Australia as a whole was assumed to apply for each region. The effect of these assumptions, combined with those for regional migration, is to imply, as shown in Table 3, a rapidly declining crude net migration rate in Region A and an increasing crude net migration rate in Region B, providing an example of the results one would expect from an economic model presented with an economic scenario of substantially higher economic growth in Region B than in Region A.

3.2 The Projected Populations

The projected populations by sex and region for 1980 to 2001, given in Table 4, indicate that Region B is projected to grow at an average annual rate of 2.69%, compared with 1.14% for Region A. These differential growth rates are the combined result of our assumption of different economic and demographic scenarios for each region and of the different initial structures of the regional populations. The relatively low economic growth in Region A

TABLE 4

ILLUSTRATIVE PROJECTIONS OF THE AUSTRALIAN POPULATION BY SEX AND REGION, 1980 to 2001

	REGION A			REGION B		
	Males	Females	Total	Males	Females	Total
1980	5480750	5500437	10981187	1837906	1795698	3633604
1981	5545667	5569495	11115162	1884303	1845049	3729352
1982	5609229	5637250	11246479	1932158	1894971	3827129
1983	5674160	5706336	11380496	1981538	1946374	3927912
1984	5739461	5775628	11515089	2032112	1999117	4031229
1985	5806445	5846442	11652887	2084719	2053754	4138473
1986	5876792	5920280	11797072	2140003	2111048	4251051
1987	5948808	5995549	11944357	2197402	2170327	4367729
1988	6022948	6072804	12095752	2257253	2232019	4489272
1989	6096868	6149856	12246724	2318653	2295287	4613940
1990	6170474	6226537	12397011	2381705	2360222	4741927
1991	6243626	6302626	12546252	2446416	2426795	4873211
1992	6316195	6378021	12694216	2512843	2494987	5007830
1993	6387902	6452568	12840470	2580931	2564862	5145793
1994	6458851	6526242	12985093	2650721	2636396	5287117
1995	6528734	6598885	13127619	2722310	2709668	5431978
1996	6597665	6670378	13268043	2795707	2784803	5580510
1997	6665588	6740857	13406445	2871077	2861866	5732943
1998	6732576	6810389	13542965	2948535	2940905	5889440
1999	6798739	6878819	13677558	3028168	3022139	6050307
2000	6864230	6946779	13811009	3110316	3105769	6216085
2001	6929044	7013606	13942650	3194980	3191878	6386858
Average Annual Growth Rate (in percentages)	1.12	1.16	1.14	2.63	2.74	2.69

results in increasing outmigration to Region B and lower overall fertility.* Although age-specific fertility rates for married and unmarried females in Region A increase faster than in Region B, lower marriage rates, in response to poorer economic conditions, lead to a fall in the proportion of married women in Region A and, therefore, to a fall in the numbers of women at risk of a marital confinement. When combined with the aging of the population (to be discussed next), this leads to a further reduction in fertility in Region A. The result of these complex interactions between demographic changes is the slower population growth in Region A and the faster growth in Region B.

The age distributions of the regional populations change substantially over the projection period, as shown in Table 5. Initially, in 1980, Region A had a slightly older population than Region B, with persons under 15 years representing 25% and persons over 55 years representing 19% of its population, compared with corresponding figures of 26% and 18%, respectively, for Region B. However, by the year 2001, the aging of the population in Region A has progressed such that only 23.54% of the population is under 15 years and 21.31% is over 55 years, compared with 26.07% and 20.18%, respectively, for Region B. It is interesting to note the effect of these changes in the age distribution of the regional populations upon the dependency ratios in each region.** There are several aspects of the Australian scene which are relevant. First, the aging process is not as severe as declining death rates would suggest because the people moving into the aged group during this projection period will be the relatively small cohort who were born

*For this projection, migration and fertility patterns for each region are part of the assumed demoeconomic scenario; however, they closely resemble the results one would expect to derive from an economic model presented with a scenario of lower economic growth in Region A than in Region B.

**The dependency ratio is calculated as the number of "dependants" (persons aged less than 15 years and greater than 64 years) divided by the "working age" population (persons aged between 15 and 64 years).

TABLE 5

PERCENTAGE DISTRIBUTION OF THE PROJECTED POPULATION IN EACH REGION BY SELECTED AGE GROUPS, 1980 to 2001

REGION A

Year	0-14	15-24	25-44	45-54	55-64	65+
1980	25.08	17.35	28.13	10.59	9.22	9.63
1981	24.87	17.22	28.38	10.41	9.32	9.80
1982	24.66	17.06	28.65	10.25	9.43	9.95
1983	24.41	16.92	29.00	10.11	9.52	10.06
1984	24.18	16.76	29.31	10.01	9.51	10.24
1985	23.88	16.64	29.64	9.93	9.45	10.46
1986	23.54	16.56	30.00	9.94	9.26	10.70
1987	23.34	16.41	30.29	9.96	9.08	10.92
1988	23.25	16.20	30.46	10.06	8.90	11.13
1989	23.24	16.01	30.54	10.20	8.72	11.29
1990	23.29	15.78	30.54	10.31	8.56	11.51
1991	23.43	15.52	30.23	10.71	8.42	11.69
1992	23.57	15.25	30.04	10.98	8.29	11.87
1993	23.70	14.94	29.96	11.23	8.18	11.99
1994	23.80	14.64	29.88	11.45	8.11	12.11
1995	23.89	14.29	29.89	11.65	8.06	12.23
1996	23.88	13.95	29.97	11.85	8.08	12.27
1997	23.86	13.70	29.95	12.06	8.12	12.31
1998	23.82	13.54	29.89	12.17	8.23	12.34
1999	23.76	13.47	29.74	12.31	8.37	12.34
2000	23.68	13.48	29.53	12.42	8.49	12.41
2001	23.54	13.62	29.25	12.28	8.85	12.46

REGION B

Year	0-14	15-24	25-44	45-54	55-64	65+
1980	25.97	17.69	28.54	9.79	8.52	9.50
1981	25.85	17.57	28.68	9.71	8.56	9.63
1982	25.70	17.41	28.87	9.65	8.64	9.73
1983	25.51	17.25	29.10	9.65	8.69	9.80
1984	25.30	17.10	29.33	9.65	8.69	9.93
1985	25.07	16.95	29.56	9.67	8.67	10.08
1986	24.81	16.89	29.72	9.78	8.54	10.25
1987	24.70	16.74	29.88	9.86	8.44	10.38
1988	24.71	16.52	29.90	10.05	8.33	10.50
1989	24.80	16.32	29.82	10.25	8.24	10.58
1990	24.93	16.11	29.71	10.36	8.18	10.71
1991	25.12	15.87	29.34	10.72	8.13	10.82
1992	25.31	15.64	29.09	10.95	8.09	10.91
1993	25.50	15.38	28.92	11.15	8.08	10.97
1994	25.68	15.10	28.78	11.31	8.08	11.04
1995	25.86	14.79	28.70	11.45	8.10	11.11
1996	25.90	14.54	28.67	11.57	8.18	11.12
1997	25.96	14.39	28.56	11.70	8.25	11.14
1998	26.01	14.31	28.41	11.72	8.40	11.15
1999	26.05	14.30	28.19	11.76	8.55	11.15
2000	26.08	14.34	27.95	11.78	8.64	11.22
2001	26.07	14.47	27.69	11.58	8.92	11.26

in the low fertility years of the Depression. Second, the Australian population of working age is still enlarged by the cohort who were born in the "baby boom" of the 1950s. Third, any projection incorporating continued international migration will tend to swell the population of working age. All these factors suggest that changes in the dependency ratio will not be substantial. In fact, for Region A, the aging of the population serves to increase the population of working age rather than the aged population. Consequently, the dependency ratio for Region A changes marginally over the projection period. In Region B, however, higher overall fertility tends to stabilize the proportion of children in the population and aging increases the population of older people, such that the dependency ratio grows over the period. However, in both regions, the results indicate the need for a shift in policy and planning emphasis away from the young and towards the old.

For a policy maker who had confidence in the appropriateness of the scenarios underlying these simulations, their consequences for expenditures on child care, education, and health care would be clear. The population of preschool children (under 5 years of age) in Region A is projected to decline in absolute numbers, at the same time that preschoolers in Region B are projected to grow in number at a faster rate than total population growth. These regions would obviously need to adopt different approaches for providing infant welfare centers, child care centers and preschools. Similarly, children of school age (5 to 17 years of age) are projected to decline in number in Region A and to increase in Region B. Educational planning in each region would need to take account of these demographic trends. For the elderly, we find that the highest rates of increase, for *both* regions, are for those persons aged 85 years and over. By the year 2001, the age group most heavily in need of health care, including long-term nursing home accommodation, is projected to become about 2½ times larger in Region A and about 3½ times larger in Region B than it was in 1980. Similar, although not quite so dramatic, growth occurs for the age group 75 to 84 years in both regions. Thus the majority of the above average growth in the aged population would be concentrated among the very old, who most need care. Planned responses to these increased demands on health and welfare expenditures would be necessary in both regions.

Changes in the marital status distribution of regions has important implications for fertility, household formation, labor force participation and expenditure on government benefits. In this projection, the marital status distribution of the regional populations changes substantially, as shown in Tables 6 and 7. The most significant change over the projection period is the growth in the proportion of divorced persons in both regions, from 1.46% (1.47%) of the population* in Region A (B) in 1980 to 4.24% (3.54%) in 2001. In terms of numbers, by 2001, there will be over 3½ (4) times the number of divorced persons in 1980 in Region A (B). The special housing and welfare needs of these people would become increasingly important to planners. Coinciding with this increase in divorcees, there is projected to be a decline in both regions in the proportions married, from 49.44% (48.62%) of the adult population in Region A (B) in 1980 to 45.65% (47.18%) in 2001. The decline in Region B has been muted by the higher marriage rates in that region.

3.3 A Demographic Assessment of the Projections

The illustrative population projection summarized above seems reasonable. The use of the multistate projection framework and an operational two-sex/marital status algorithm ensures consistency along a number of dimensions. The use of model schedules in the projection procedure guarantees that the various projected rates of transition between statuses will maintain reasonable age profiles in the future. Checks on the "reasonableness" of the projections can be made by calculating life tables and generating alternative projections.

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*The adult population is defined to be all persons 15 years of age and above.

TABLE 6

PERCENTAGE DISTRIBUTION OF THE PROJECTED POPULATION OF MALES IN EACH REGION BY MARITAL STATUS, 1980 to 2001

REGION A

Year	Never Married 0-14	Never Married 15+	Married	Divorced	Widowed
1980	25.75	21.36	49.44	1.46	2.00
1981	25.53	21.55	49.20	1.70	2.02
1982	25.32	21.78	48.97	1.89	2.03
1983	25.07	22.05	48.67	2.16	2.05
1984	24.85	22.29	48.41	2.39	2.06
1985	24.56	22.59	48.18	2.59	2.07
1986	24.23	22.96	47.95	2.77	2.08
1987	24.04	23.20	47.73	2.94	2.09
1988	23.94	23.35	47.51	3.10	2.10
1989	23.94	23.39	47.30	3.26	2.11
1990	24.00	23.38	47.10	3.41	2.11
1991	24.15	23.27	46.91	3.54	2.12
1992	24.30	23.17	46.74	3.67	2.13
1993	24.43	23.09	46.58	3.77	2.13
1994	24.55	23.03	46.43	3.86	2.14
1995	24.64	22.99	46.29	3.93	2.15
1996	24.63	23.06	46.16	4.00	2.15
1997	24.62	23.13	46.04	4.06	2.16
1998	24.58	23.22	45.92	4.11	2.16
1999	24.53	23.33	45.82	4.16	2.16
2000	24.44	23.46	45.73	4.20	2.17
2001	24.31	23.63	45.65	4.24	2.17

REGION B

Year	Never Married 0-14	Never Married 15+	Married	Divorced	Widowed
1980	26.40	21.60	48.62	1.47	1.91
1981	26.31	21.90	48.19	1.68	1.92
1982	26.14	22.02	48.03	1.86	1.94
1983	25.95	22.16	47.88	2.05	1.97
1984	25.76	22.28	47.77	2.21	1.98
1985	25.53	22.43	47.68	2.36	2.00
1986	25.28	22.63	47.58	2.49	2.02
1987	25.18	22.67	47.50	2.61	2.03
1988	25.20	22.61	47.42	2.73	2.04
1989	25.30	22.46	47.34	2.85	2.05
1990	25.44	22.26	47.28	2.96	2.06
1991	25.64	22.01	47.22	3.07	2.06
1992	25.84	21.76	47.18	3.15	2.06
1993	26.04	21.51	47.15	3.23	2.07
1994	26.23	21.28	47.13	3.29	2.07
1995	26.41	21.06	47.12	3.34	2.07
1996	26.47	20.97	47.11	3.39	2.07
1997	26.54	20.87	47.11	3.42	2.06
1998	26.59	20.78	47.11	3.46	2.06
1999	26.65	20.68	47.13	3.49	2.06
2000	26.68	20.60	47.15	3.52	2.05
2001	26.68	20.55	47.18	3.54	2.05

TABLE 7

PERCENTAGE DISTRIBUTION OF THE PROJECTED POPULATION OF FEMALES IN EACH REGION BY MARITAL STATUS, 1980 TO 2001

REGION A

Year	Never Married 0-14	Never Married 15+	Married	Divorced	Widowed
[illegible]	24.41	15.67	49.29	1.93	8.70
[illegible]	24.20	15.86	48.99	2.18	8.77
[illegible]	23.99	16.03	48.75	2.41	8.83
1983	23.73	16.24	48.43	2.71	8.88
1984	23.50	16.42	48.16	2.99	8.93
1985	23.20	16.67	47.92	3.24	8.97
1986	22.85	16.99	47.68	3.47	9.01
1987	22.64	17.18	47.45	3.69	9.04
1988	22.55	17.26	47.21	3.91	9.06
1989	22.54	17.26	46.99	4.13	9.08
1990	22.58	17.21	46.77	4.35	9.10
1991	22.71	17.07	46.55	4.55	9.12
1992	22.84	16.93	46.36	4.73	9.14
1993	22.96	16.81	46.18	4.90	9.15
1994	23.06	16.71	46.01	5.05	9.17
1995	23.13	16.64	45.86	5.19	9.18
1996	23.12	16.66	45.71	5.31	9.19
1997	23.10	16.68	45.58	5.43	9.20
1998	23.06	16.73	45.47	5.53	9.21
1999	23.00	16.78	45.37	5.63	9.22
[illegible]	22.91	16.36	45.28	5.72	9.2[illegible]
[illegible]	22.73	16.98	45.21	5.81	9.23

REGION B

Year	Never Married 0-14	Never Married 15+	Married	Divorced	Widowed
1980	25.53	15.19	49.45	1.73	8.10
1981	25.37	15.41	49.15	1.96	8.10
1982	25.23	15.57	48.93	2.17	8.11
1983	25.05	15.73	48.72	2.39	8.11
1984	24.82	15.91	48.56	2.60	8.11
1985	24.60	16.08	48.43	2.79	8.10
1986	24.32	16.30	48.31	2.97	8.09
1987	24.20	16.37	48.20	3.15	8.08
1988	24.20	16.32	48.09	3.33	8.05
1989	24.28	16.17	48.00	3.51	8.03
1990	24.40	15.99	47.91	3.69	8.01
1991	24.58	15.74	47.84	3.86	7.98
1992	24.76	15.49	47.78	4.01	7.95
1993	24.95	15.24	47.74	4.15	7.92
1994	25.13	14.99	47.71	4.28	7.89
1995	25.29	14.76	47.69	4.39	7.86
1996	25.33	14.66	47.69	4.50	7.83
1997	25.38	14.54	47.70	4.59	7.79
1998	25.41	14.43	47.73	4.68	7.76
1999	25.45	14.30	47.77	4.76	7.72
2000	25.46	14.19	47.83	4.83	7.69
2001	25.45	14.10	47.90	4.90	7.65

3.3.1 Life Tables

Tables 8 through 11 set out the expectancies of remaining lifetime in each marital state implied by the projection. The expectancies refer to 20-year-old males and females, and they have been calculated for two points in time: the base year, 1980/81, and the target year, 2000/01. They reveal, for example, that a 20-year-old never married female residing in Region A (B) could expect to remain never married for about 16.6 (16.0) years on 1980/81 rates and 17.5 (12.4) years on 2000/01 rates. In summary, the 20-year illustrative projection of marital status transitions is anticipating, for Region A, increases in the time spent in all states, particularly never married and divorced. For Region B, the projection expects a decline in the time spent in the never married state and increases in the time spent in all other states, particularly divorced and married. Thus, compared with Region A, the higher rates of marriage and divorce in Region B, prompted by its higher economic growth, lead to shorter time being spent in the never married state (as expected) and in the divorced state. This implies that while people may be more likely to divorce in Region B, they are also more likely to remarry and therefore can expect to spend a smaller part of their life in the divorced state than people in Region A.

It is interesting to compare these results with data for another country (the Netherlands) at approximately comparable points in time, as in Table 12. For convenience, we have eliminated the regional dimension and have held constant the mortality regime in both sets of Australian expectancies. Although the expectancy of remaining in the never married state for 20-year-old females is consistently lower for the Netherlands, both countries have experienced increases of similar magnitudes during the 1970s: from 6 to 12 years between 1972 and 1978 in the Netherlands and from 11 to 16 years between 1975 and 1980 in Australia. Given the dramatic decline in the popularity of marriage in the 1970s, the magnitude of the projected changes for both regions in time spent in the never married state appears feasible. Of particular interest is the projected retardation in the trend of declining

TABLE 8

EXPECTANCIES OF REMAINING LIFETIME IN EACH MARITAL STATE, BY REGION, FOR 20-YEAR OLD AUSTRALIAN MALES: 1980/81 DATA

	Remaining life expectancy								
	Region A				Region B				
Status at age 20	Never Married	Married	Divorced	Widowed	Never Married	Married	Divorced	Widowed	Total
Region A									
Never Married	13.37	27.50	1.78	1.74	1.94	5.52	0.38	0.51	52.75
Married	0	41.27	2.57	2.20	0	6.88	0.50	0.61	54.04
Divorced	0	39.16	4.45	2.18	0	7.01	0.56	0.61	53.97
Widowed	0	26.04	1.65	19.72	0	4.18	0.28	1.28	53.15
Region B									
Never Married	3.50	11.13	0.77	0.92	12.14	21.93	1.38	1.34	53.10
Married	0	14.52	1.03	1.13	0	33.99	2.03	1.70	54.40
Divorced	0	14.33	1.10	1.13	0	32.20	3.90	1.69	54.34
Widowed	0	7.65	0.51	2.09	0	22.66	1.40	19.35	53.65

TABLE 9

EXPECTANCIES OF REMAINING LIFETIME IN EACH MARITAL STATE, BY REGION FOR 20-YEAR OLD AUSTRALIAN MALES: 2000/01 PROJECTION

	Remaining life expectancy								
	Region A				Region B				
Status at age 20	Never Married	Married	Divorced	Widowed	Never Married	Married	Divorced	Widowed	Total
Region A									
Never Married	14.98	24.81	2.51	1.61	2.40	8.50	0.68	0.71	56.20
Married	0	38.50	3.96	2.06	0	11.12	0.92	0.89	57.46
Divorced	0	37.02	5.88	2.07	0	10.66	0.90	0.87	57.40
Widowed	0	22.04	1.94	21.18	0	7.52	0.54	3.41	56.64
Region B									
Never Married	3.18	12.42	1.21	0.99	11.14	24.37	2.04	1.49	56.84
Married	0	15.93	1.61	1.21	0	34.45	2.84	1.75	57.80
Divorced	0	15.50	1.58	1.20	0	33.48	4.27	1.76	57.78
Widowed	0	7.40	0.59	2.68	0	22.90	1.72	21.87	57.16

TABLE 10

EXPECTANCIES OF REMAINING LIFETIME IN EACH MARITAL STATE, BY REGION, FOR 20-YEAR OLD AUSTRALIAN FEMALES: 1980/81 DATA

Status at age 20	Remaining life expectancy								
	Region A				Region B				
	Never Married	Married	Divorced	Widowed	Never Married	Married	Divorced	Widowed	Total
Region A									
Never Married	14.43	24.96	2.83	6.72	2.14	5.72	0.66	2.24	59.70
Married	0	37.04	4.01	8.39	0	7.37	0.88	2.76	60.44
Divorced	0	34.60	6.46	8.34	0	7.28	0.97	2.75	60.40
Widowed	0	25.75	2.92	20.78	0	5.89	0.68	4.00	60.02
Region B									
Never Married	4.57	10.72	1.38	3.69	11.41	20.79	2.04	5.43	60.03
Married	0	13.65	1.81	4.45	0	31.20	2.87	6.74	60.72
Divorced	0	13.63	2.02	4.47	0	28.91	4.98	6.67	60.68
Widowed	0	10.55	1.37	6.85	0	22.29	2.19	17.11	60.36

TABLE 11

EXPECTANCIES OF REMAINING LIFETIME IN EACH MARITAL STATE, BY REGION, FOR 20-YEAR OLD AUSTRALIAN FEMALES: 2000/01 PROJECTION

Status at age 20	Remaining life expectancy								
	Region A				Region B				
	Never Married	Married	Divorced	Widowed	Never Married	Married	Divorced	Widowed	Total
Region A									
Never Married	15.38	22.82	4.18	5.74	2.08	8.69	1.34	2.86	63.11
Married	0	33.09	5.98	7.00	0	12.06	1.90	3.74	63.76
Divorced	0	31.54	8.34	7.07	0	11.31	1.84	3.62	63.72
Widowed	0	21.89	3.99	20.16	0	9.62	1.47	6.23	63.32
Region B									
Never Married	3.37	11.93	2.25	3.66	9.02	24.00	3.69	5.64	63.55
Married	0	14.54	2.80	4.27	0	31.36	4.60	6.40	63.96
Divorced	0	14.02	2.76	4.19	0	30.45	6.07	6.46	63.95
Widowed	0	11.71	2.16	8.62	0	22.21	3.43	15.47	63.60

TABLE 12

EXPECTANCIES OF REMAINING LIFETIME IN EACH MARITAL STATE FOR 20-YEAR OLD FEMALES IN TWO DIFFERENT COUNTRIES AT TWO MOMENTS IN TIME

1. Australia, 1980/81

Status at age 20	Remaining life expectancy				
	Never Married	Married	Divorced	Widowed	Total
Never married	16.43	30.82	3.42	8.98	59.65
Married	0	44.46	4.77	11.13	60.36
Divorced	0	41.98	7.25	11.08	60.31
Widowed	0	31.90	3.54	24.53	59.97

2. Australia, 1975/76 (1980/81 mortality)

Status at age 20	Remaining life expectancy				
	Never Married	Married	Divorced	Widowed	Total
Never married	11.01	34.14	4.01	9.48	58.64
Married	0	43.47	4.92	10.77	59.16
Divorced	0	40.88	7.51	10.71	59.10
Widowed	0	33.64	3.96	21.25	58.86

3. Netherlands, 1978*

Status at age 20	Remaining life expectancy				
	Never Married	Married	Divorced	Widowed	Total
Never married	12.15	34.43	3.93	8.96	59.47
Married	0	44.20	5.19	10.39	59.78
Divorced	0	36.18	13.72	9.67	59.57
Widowed	0	26.37	2.95	27.75	57.07

4. Netherlands, 1972*

Status at age 20	Remaining life expectancy				
	Never Married	Married	Divorced	Widowed	Total
Never married	5.88	39.81	2.47	9.86	58.02
Married	0	45.07	2.74	10.36	58.17
Divorced	0	40.64	7.28	10.15	58.07
Widowed	0	31.74	1.96	23.35	57.05

*Source: Koesoebjono (1981).

popularity of marriage in Region A and the reversal of this trend in the more prosperous Region B.

3.3.2 Alternative Projections

The illustrative projection forecasts an Australian population of 20.3 million by the year 2001. Table 13 sets out a summary of the results obtained in the illustrative projection and in two alternative projections. The first is a fixed-rates projection which holds constant the transition and growth regime of the base-year period and ignores the impacts of international migration. The second adopts the changing rates used in the illustrative projection but sets net immigration equal to zero. The differences between these two alternative projections, therefore arise solely as a consequence of replacing base-year rates with the changing rates generated by the demographic and economic scenarios. And the differences between the second alternative projection and the illustrative projection are solely a consequence of the impacts of international migration.

Current patterns of international migration, through their direct and indirect impacts, should contribute approximately 2.4 million individuals to Australia's total population over the next two decades. Of these, 30.0% will contribute to the population of Region B. Given that Region B represented only 24.9% of the nation's population in 1980, its higher economic growth is projected to attract more than its share of international migrants. During the period, forecasted patterns of fertility, mortality, migration, and marital status change should add almost 1½ million individuals to the national population that would have arisen if 1980/81 rates had remained unchanged. Of these, about two-thirds will be added to the population of Region B, indicating the substantial effect of the higher economic growth assumed for Region B. The contributions of international migration and natural increase in Australia's national population appear reasonable in the light of its recent history suggesting that the illustrative projection has produced a generally believable forecast of Australia's future national population. At the regional level, the projections are more dependent

TABLE 13

ALTERNATIVE PROJECTIONS OF THE AUSTRALIAN POPULATION BY SEX AND REGION, 1980 TO 2001

	Region A			Region B			Australia		
Year	Males	Females	Total	Males	Females	Total	Males	Females	Total
1980	5,480,750	5,500,437	10,981,187	1,837,906	1,795,698	3,633,604	7,318,656	7,296,135	14,614,791
				Fixed Rates Projection (Zero Net Immigration)					
2001	5,765,158	5,868,028	11,633,186	2,392,381	2,416,407	4,808,788	8,157,539	8,284,437	16,418,976
				Changing Rates Projection (Zero Net Immigration)					
2001	6,091,776	6,152,308	12,244,084	2,829,657	2,836,302	5,665,959	8,921,432	8,988,609	17,910,041
				Changing Rates Projection (Nonzero Net Immigration)					
2001	6,929,042	7,013,603	13,942,645	3,194,975	3,191,871	6,386,846	10,205,473	10,124,017	20,329,490

upon our somewhat exaggerated scenarios of differential regional growth, but they do provide an interesting illustration of the substantial effects that varying economic and demographic growth can have upon regional populations.

4. CONCLUDING REMARKS

The facility for multistate projections which has been outlined in this paper provides highly disaggregated projections of population by sex, age, marital status, and region within a tightly integrated framework that respects demographic accounting identities and that faithfully tracks through time the changes in the age and marital status profiles of regional populations. At the same time it allows reasonable latitude for demographic events to be influenced by changing economic and social conditions. This approach is made feasible by the condensation of the time series of changes in important demographic variables into a manageable set of descriptive statistics amenable to economic modeling, which are then available for forging links between demographic changes and wider economic influences. By allowing this technique to separate the effects of changes in behavior from changes in the demographic structure of the regional populations due to aging and previous history, the projection facility has simplified the task of the economic model by limiting its role to accounting for behavioral changes alone and not those arising from the evolutionary dynamics of population growth.

To date the facility has not been fully implemented, but, as the illustrative projection has shown, such an implementation is certainly feasible. Research efforts are currently being directed towards the expansion of the economic model to incorporate the modeling of parameters of model schedules of fertility and regional migration. Such a model would complete the projection facility outlined in this paper and provide a tool for the analysis of the effects of economic variables upon demographic behavior. In this paper, however, we have concentrated only on part of the relationship between economic and demographic variables. The changing demography of a region will undoubtedly affect the economy of that region via the impacts on consumer demand, housing demand, and labor supply. The facility presented here must therefore be incorporated into a wider model of simultaneously determined economic and demographic growth. Work is currently proceeding in this direction.

REFERENCES

Becker, G.S. (1960) An Economic Analysis of Fertility. In National Bureau of Economic Research, *Demographic and Economic Changes in Developed Countries*. Princeton, New Jersey: Princeton University Press.

Becker, G.S. (1964) *Human Capital*. New York: National Bureau of Economic Research, Columbia Press.

Becker, G.S. (1965) A Theory of the Allocation of Time. *Economic Journal* 75:493-517.

Becker, G.S. (1974). A Theory of Marriage. In *Economics of the Family*, edited by T.W. Schultz. Chicago and London: University of Chicago Press.

Becker, G.S., E.M. Landes, and R.T. Michael (1977) An Economic Analysis of Marital Instability. *Journal of Political Economy* 85(6):1141-1187.

Benjamin, B., and H.J. Pollard (1980) *The Analysis of Mortality and Other Actuarial Statistics*. London: Heinemann.

Brass, W. (1971) On the Scale of Mortality. Pages 69-110 in *Biological Aspects of Demography*, edited by W. Brass. London: Taylor and Francis.

Brooks, C., D. Sams, and P. Williams (1980) *A Time Series of Smooth Approximations for Age, Sex, and Marital Status Specific Death Rates in Australia, 1950/51 to 1975/76 with a Projection to the Year 2000*. Research Memorandum. Melbourne: IMPACT Project, BACHUROO Module.

Brooks, C., D. Sams, and L. Williams (1982) *An Econometric Model of Fertility, Marriage, Divorce and Labour Force Participation for Australian Women, 1921/22 to 1975/76.* Preliminary Working Paper BP-29. Melbourne: IMPACT Project.

Butz, W.P., and M.P. Ward (1979) The Emergence of Counter-Cyclical US Fertility. *American Economic Review* 69:318-328.

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

Coale, A.J., and D.R. McNeil (1972) The Distribution by Age of the Frequency of First Marriage in a Female Cohort. *Journal of the American Statistical Association* 67:743-9.

Coale, A.J., and T.J. Trussell (1974) Model Fertility Schedules: Variations in the Age Structure of Childbearing in Human Populations. *Population Index* 40(2):185-258.

Day, L.H. (1963) Divorce in Australia. *The Australian Quarterly* 48(2).

Dodd, S.C. (1950) The Interactance Hypothesis: A Gravity Model Fitting Physical Masses and Human Groups. *American Sociological Review* 15:245-256.

Filmer, R., and R. Silberberg (1977) *Fertility, Family Formation and Female Labour Force Participation in Australia, 1922-1974.* Preliminary Working Paper BP-08. Melbourne: IMPACT Project.

Food and Agriculture Organization (1976) *A Systems Simulation Approach to Integrated Population and Economic Planning with Special Emphasis on Agricultural Development and Employment: An Experimental Study in Pakistan.* PA 4/1 INT/73/P02, Working Paper Series 11. Rome: Food and Agriculture Organization.

Gallway, L.E. (1969) Age and Labor Mobility Patterns. *Southern Economic Journal* 36(2):171-180.

Gordon, P., and J. Ledent (1981) Modeling the Dynamics of a System of Metropolitan Areas: A Demoeconomic Approach. *Environment and Planning A* 12:125-133.

Greenwood, M.J. (1973) Urban Economic Growth and Migration: Their Interaction. *Environment and Planning* 5:91-112.

Greenwood, M.J. (1975) Research on Internal Migration in the United States: A Survey. *Journal of Economic Literature* 13(2):397-443.

Heckman, J. (1974) Shadow Prices, Market Wages and Labor Supply. *Econometrica* 42(4):674-694.

Heligman, L., and J.H. Pollard (1979) *The Age Pattern of Mortality.* Research Paper 185. Sydney: Macquarie University, School of Economic and Financial Studies.

Hoem, J.M., D. Madsen, J.L. Nelson, E.M. Ohlsen, H.O. Hansen and B. Lennermalm (1981) Experiments in Modelling Recent Danish Fertility Curves. *Demography* 18(2):231-244.

Hutchens, R.M. (1979) Welfare, Remarriage and Marital Search. *American Economic Review* 69(3):369-379.

Keeley, M.C. (1977) The Economics of Family Formation. *Economic Inquiry* 15:238-250.

Keeley, M.C. (1979) An Analysis of the Age Pattern of First Marriage. *International Economic Review* 20(2):527-544.

Kelley, A.C. (1965) International Migration and Economic Growth: Australia, 1865-1936. *Journal of Economic History* 25(3):333-354.

Kelley, A.C., and R.M. Schmidt (1979) Modelling the Role of Government Policy in Post-War Australian Immigration. *The Economic Record* 55(149):127-135.

Kelley, A.C., and J.G. Williamson (1980) *Modeling Urbanization and Economic Growth.* Research Report RR-80-22. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Koesoebjono, S. (1981) *Nuptiality Tables for the Female Population of the Netherlands, 1978; An Application of Multidimensional Demography.* Working Paper 20. Voorburg, Netherlands: Netherlands Interuniversity Demographic Institute.

Lancaster, K.J. (1966) A New Approach to Consumer Theory. *Journal of Political Economy* 74:132-157.

Ledent, J. (1978) Regional Multiplier Analysis: A Demographic Approach. *Environment and Planning A* 10:537-560.

Ledent, J., and P. Gordon (1981) A Framework for Modeling Interregional Population Distribution and Economic Growth. *International Regional Science Review* 6(1):85-90.

Long, L.H., and K.A. Hansen (1979) *Reasons for Interstate Migration.* Current Population Reports, Series P-23,18. Washington, D.C.: US Department of Commerce, Bureau of the Census.

Lowry, I.S. (1966) *Migration and Metropolitan Growth: Two Analytical Models.* San Francisco: Chandler Publishing Co.

Miller, E. (1973) Is Out-Migration Affected by Economic Conditions? *Economic Journal* 39(3):396-405.

Mincer, J. (1963) Market Prices, Opportunity Costs and Income Effects. In *Measurement in Economics: Studies in Mathematical Economics and Econometrics in Memory of Yehuda Grunfeld*, edited by C. Christ. Stanford, California: Stanford University Press.

Pope, D. (1976) *The Peopling of Australia: United Kingdom Immigration from Federation to the Great Depression.* Ph.D. thesis. Canberra: Australian National University.

Powell, A.A. (1982) Aspects of the Design of BACHUROO, An Economic Demographic Model of Labor Supply. In *Modeling Growing Economies in Equilibrium and Disequilibrium: Proceedings of an IIASA Meeting, 10-13 November 1980*, edited by A.C. Kelley, W.C. Sanderson, and J.G. Williamson. Forthcoming.

Quigley, J.M. (1972) An Economic Model of Swedish Emigration. *The Quarterly Journal of Economics* 86(1):111-126.

Rodgers, G.B., M.J.D. Hopkins, and R. Wéry (1976) *Economic-Demographic Modelling for Development Planning. Bachue-Phillipines.* Population and Employment Working Paper 45. Geneva: International Labour Organization.

Rogers, A. (ed.)(1980) Essays in Multistate Demography. Special issue of *Environment and Planning A* 12(5):485-622.

Rogers, A. (ed.)(1981) *Advances in Multiregional Demography.* Research Report RR-81-6. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Rogers, A., R. Raquillet, and L.J. Castro (1978) Model Migration Schedules and Their Applications. *Environment and Planning A* 10(5):475-502.

Rogers, A., and L.J. Castro (1981a) *Model Migration Schedules.* Research Report RR-81-30. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Rogers, A., and L.J. Castro (1981b) Age Patterns of Migration: Cause-specific Profiles. Pages 125-59 in *Advances in Multiregional Demography*, edited by A. Rogers. Research Report RR-81-6. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Sams, D. (1979a) *The Demographic Core of the IMPACT Project, An Overview.* Preliminary Working Paper BP-18. Melbourne: IMPACT Project.

Sams, D. (1979b) *The Performance of the Births Block of the Demographic Core.* Research Memorandum. Melbourne: IMPACT Project, BACHUROO Module.

Sams, D. (1981a) *A Two-sided Marriage Model for the IMPACT Population Projection Facility.* Research Memorandum. Melbourne: IMPACT Project, BACHUROO Module.

Sams, D. (1981b) *The Double-Exponential Function.* Research Memorandum. Melbourne: IMPACT Project, BACHUROO Module.

Sams, D., and P. Williams (1980) *The IMPACT Project's Facility for Disaggregated Population Projections: A Brief Exposition and Progress Report.* Preliminary Working Paper BP-22. Melbourne: IMPACT Project.

Sams, D., and P. Williams (1982) *Some Projections of Australian Population and Labor Force, 1980 to 2001.* Preliminary Working Paper BP-30. Melbourne, IMPACT Project.

Schmidt, R.M. (1980) *The Demographic Dimensions of Economic-Population Modeling.* Unpublished Ph.D. dissertation. Durham, North Carolina: Duke University.

Schwartz, A. (1973) Interpreting the Effect of Distance on Migration. *Journal of Political Economy* 81(5):1153-1169.

Simon, J.L. (1976) Population Growth May Be Good for LDCs in the Long Run: A Richer Simulation Model. *Economic Development and Cultural Change* 24(2):309-337.

Somermeijer, W.H. (1961) Een analyse van de binnen-landse migratie in Nederland tot 1947 en van 1948-57 (An analysis of the Internal Migration in the Netherlands until 1947 and from 1948-1957). *Statistische en Econometrische Onderzoekugen.*

Todaro, M. (1969) A Model of Labor, Migration, and Urban Unemployment in Less Developed Countries. *American Economic Review* 59:138-148.

United Nations (1967) *Methods of Estimating Basic Demographic Measures from Incomplete Data.* New York: United Nations.

Wadensjö, E. (1977) Some Factors Determining International Migration. In *Demographic, Economic, and Social Interaction,* edited by A.E. Andersson and I. Holmberg. Cambridge, Mass.: Ballinger Publishing Co.

Wilkinson, M. (1970) European Migration to the United States: An Econometric Analysis of Aggregated Labor Supply and Demand. *The Review of Economics and Statistics* 52(3):242-279.

Williams, P. (1981) *Marriage and Divorce in Australia: A Time Series of Fitted Distributions, 1921/22 to 1975/76.* Working Paper B-20. Melbourne: IMPACT Project.

Williams, P. (1982) *Notes on Illustrative Projections of the Australian Population Disaggregated by Age, Sex, Marital Status and Region Using the IMPACT Population Projection Facility.* Research Memorandum. Melbourne: IMPACT Project, BACHUROO Module.

Willis, R.J. (1974) Economic Theory of Fertility Behavior. In *Economics of the Family*, edited by T.W. Schultz. Chicago and London: University of Chicago Press.

Zipf, G.K. (1946) The P_1P_2/D Hypothesis: On the Intercity Movement of Persons. *American Sociological Review* 11(6):677-686.

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