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IMPACT is an economic and demographic research project conducted by Commonwealth Government agencies in association with the Faculty of Economics and Commerce at The University of Melbourne and the School of Economics at La Trobe University.

THE IMPACT POPULATION PROJECTION FACILITY :

A NON-TECHNICAL OVERVIEW

by

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and

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1. PREAMBLE

A facility for the projection of the Australian population, hereafter referred to as the IMPACT Population Projection Facility, has completed a first round of development at the IMPACT Project.[1] The initial version of the Facility was released for use by policy analysts in December 1982. Although Australia is already well serviced by the Australian Bureau of Statistics[2] in the area of demographic projections, the public accessibility of the IMPACT Facility, and the provision of courses for training personnel outside the Project in its use, make the Facility unique in Australia at this time. Several papers illustrating the use of the Facility are publicly available.[3]

The IMPACT Project's approach to population projection possesses several interesting features which enhance its potential value as a tool for policy analysis. The basic structure of the Projection Facility is discussed in Sams and Williams (1983c). This material is not repeated here. Instead, we focus mainly on the following special features of the Facility:

(i) its integration within a medium term model of the Australian economy;

(ii) the achievement within it of consistency between demographic stocks and flows at a high level of disaggregation;

and

(iii) its use of econometric models of fertility, marriage, divorce and female labour force participation and of household formation.

Our material is organised into sections which correspond to (i), (ii) and (iii), plus a summary and perspectives for further research.

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2. THE MEDIUM TERM MODEL

An unusual and distinctive feature of the IMPACT Population Projection Facility is that it has been designed as an integral part of an economic model; namely, the IMPACT Project's medium term model of the Australian economy. The medium term model will consist of three linked modules: a macroeconomic module, MACRO;[4] an industry structure module, ORANI;[5] and a labour supply module, BACHUROO.[6] The interconnections between the three modules are shown schematically in Figure 1, taken from Powell and Parmenter (1979).

The medium term model is designed as a dynamic system to respond to external conditions and to allow interconnections and feedbacks between the macroeconomy, industry structure and the labour market. Once it is supplied externally with initial values for the endogenous variables at the beginning of the projection period and with the values of the exogenous variables during the period, its equations can be solved simultaneously to give projections of the endogenous variables throughout the period. Because of this design feature, the medium term model will be able to provide fully consistent projections of economic and demographic variables. However, despite provision for these interconnections, the three modules of the medium term model have been designed to allow individual solution, so that they can be used independently for specific policy simulations.

The Population Projection Facility is contained within the labour supply module, BACHUROO. BACHUROO is designed to determine the size and

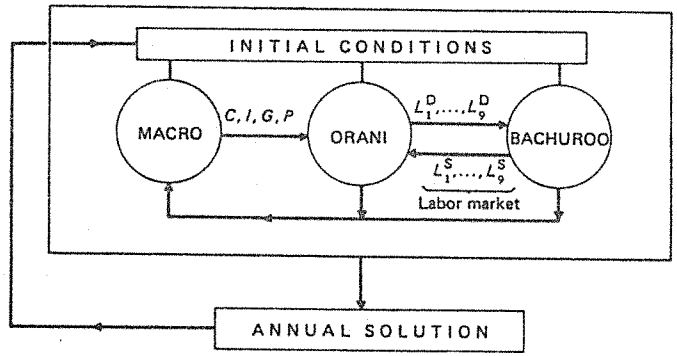

Figure 1 : Simplified Diagram of Medium Term Model

The levels of real consumption C , real investment I , real government spending G , and the general price level P , may be thought of as originating in MACRO. ORANI disaggregates these into 113 input-output industries and determines relative prices of commodities, imports and exports by I-O industry, and (if wage relativities are given) labour demands by nine occupations. BACHUROO determines the supplies of labour by occupation. Excess demand for or supply of labour can feed back into the macroeconomic environment. Interactively the three modules will, given a set of initial conditions, produce an annual solution which then determines a new set of initial conditions for a second annual solution; and so on.

15. The modelling of migration has been investigated in two IMPACT papers, but it has not been possible to develop a satisfactory model. See Caddy, Jackson and Powell (1978) and Kelley and Schmidt (1978).

16. This technique is described in Brooks, Sams and Williams (1980).

17. Parity progression ratios have been calculated for Australia by Spencer (1974) and Pollard (1975).

18. See Becker (1960), (1965), and (1974), and Becker, Landes and Michael (1977).

19. The computer implementation of the model is available on the CSIRONET computing system and can be accessed by those with appropriate computing facilities, expertise and finance. A user's guide to the computer implementation is given in Sams and Williams (1982b). Anyone who wishes to run their own projections should contact the IMPACT Project.

FOOTNOTES

1. For a full non-technical discussion of the IMPACT Project, see Powell (1977), Powell and Parmenter (1979), and Powell (forthcoming 1983).

2. See, for example, Australian Bureau of Statistics (1982).

3. For example, see Sams and Williams (1982a), Williams and Sams (1982), Williams, Sams and Martin (1982) and Sams and Williams (1983a) and (1983b).

4. See Bacon and Johnston (1976), Cooper and McLaren (1980), and Cooper (1983).

5. See Dixon, Parmenter, Sutton and Vincent (1982).

6. See Powell (1983).

7. See Craigie, Parham and Ryland (1979), and Powell, Parham, Sams and Rimmer (1982).

8. Female labour force participation rates are projected as part of an econometric model reported in Section 4.1 of this paper, and reported more fully in Brooks, Sams and Williams (1982). At this stage in the development of the Facility, male labour force participation rates are supplied exogenously.

9. Households are projected as part of an econometric model of household headship rates reported in Section 4.2 of this paper, and more fully in Williams and Sams (1981).

10. See Brown and Hall (1978) and (1980) and Williams, Brooks and Sams (1980).

11. Data for the period 1976/77 to 1980/81 have recently become available, but have not as yet been published.

12. The marital status definitions adopted are as legally defined and as available in the Demographic Databank. Although it would be preferable to adopt a disaggregation which included the marital states of permanently separated and de facto marriage, data on these states are not readily available.

13. For a full description of this technique and a report of its use for the marital status changes of females and males over the period 1921/22 to 1975/76, see Williams (1981).

14. These data are available from various issues of publications of the Australian Bureau of Statistics, Demography (to 1971), Marriages (from 1972), and Divorces (from 1972).

skill composition of the labour force[7] by using an integrated framework of demographic accounting which supplies consistent estimates of Australian population, labour force[8] and households.[9] Projections of the labour force and number of households are of interest in their own right, but are also potentially important in linking with labour demands from, and in supplying household expenditures to, ORANI and MACRO.

The Facility has been developed in the context of this framework and is fully consistent with it. Specifically, population projections are derived from a model which takes into account interrelationships between marriage, divorce and fertility, and which explicitly incorporates important enconomic and social influences on family formation behaviour. As well, the econometric models projecting labour force participation and household headship rates are subject to the same economic and demographic scenarios as those determining the population projections.

3. A CONSISTENT FRAMEWORK FOR THE PROJECTION OF DISAGGREGATED POPULATIONS

When devising a facility for the projection of population, it is important to recognise three aspects of demographic change.

Firstly, there are well defined relationships existing between some demographic phenomena; for example, the number of divorced people at the end of each year is simply the number at the beginning of the year plus divorces and arrivals of divorced migrants less remarriages of divorced persons, deaths and emigration of divorcees during the year. Such relationships are represented in the Facility by a set of demographic accounting identities.

Secondly, the frequencies of demographic events are directly influenced by the current age and marital status profile of the population. For example, the number of nuptial births will be influenced by the number of married women (that is, the population "at risk" of a nuptial birth), which in turn will have been influenced by the number of marriages in previous periods. This is achieved by specifying demographic, labour supply and household formation behaviour in terms of sex, age and marital status specific rates, which are applied to mechanically updated estimates of the appropriate populations.

Finally, there are changes in demographic phenomena which are not explained by such direct relationships. They derive from changes in

6. PERSPECTIVES FOR FURTHER RESEARCH

The current version of the Facility should be viewed as an initial attempt to build an economic-demographic model which will permit the detailed analysis of the future size and composition of the Australian population, labour force and number of households, and the relationship of these to the economic environment. The Facility has been successful in developing a technique which enables the population to be projected at a highly disaggregated level, which includes marital status detail, and in illustrating how this technique can be linked to a suite of econometric models. As well, the econometric model of household formation provides a well-structured and transparent representation of the effect of changes in economic conditions on household headship rates.

However, there do exist several opportunities for the further development of the Facility. The most urgent of these would appear to be:

(i) the development of an appropriate database which would enable better econometric modelling of Australian fertility behaviour;

(ii) the integrated modelling of labour force participation rates for males and females and their relationship to economic and demographic variables;

and

(iii) the extension of the Facility to include the modelling of household demand.

population levels on the one hand, and economic variables such as the size of the labour force and the number of households on the other. Each endogenous variable projected by the Facility may be subject to the influence of other variables calculated within the Facility itself, projected elsewhere within the IMPACT medium term model, or supplied externally. Although detailed, the structure of the relationships incorporated into the Facility is sufficiently clear to allow full explanation of the economic-demographic interactions which underlie projections made with it. A challenge facing users of the Facility is to exploit to best advantage the potential transparency of the mechanisms involved.

human attitudes and behaviour, such as changes in the size of family desired by couples and changes in the attitudes of young people towards marriage. These behavioural aspects of demographic events are determined via econometric models which relate certain demographic summary statistics to economic and social variables.

Thus, the Population Projection Facility has been designed to provide a tightly integrated framework which will ensure that accounting identities are automatically maintained, that current demographic events are directly influenced by the age and marital status profile of the population, and that econometric techniques can be applied to explain the less tangible features of demographic change. The nature of this framework is the subject of this section.

3.1 Consistency in Population Projections

The analysis of population is made easier by the well-defined relationships existing between stocks and flows. One of the strengths of the demographic accounting approach adopted in the Population Projection Facility is that it replicates the processes whereby population stocks, for each sex, age and marital status, change according to the numbers of births, deaths, migrant arrivals and departures, marriages, divorces and widowings. For instance, in each year the number of never married women at each age is decreased by the number of first marriages, deaths and migrant departures and increased by the number of migrant arrivals. At the same time, these first marriages will increase the number of married women at that age. Similarly, the deaths of married men will result not only in a reduction of

the numbers of married men, but also in an increase in the numbers of widowed women and a decrease in the numbers of married women. To ensure that these processes are taken into account when deriving the end-of-year population of each sex, age and marital status, the Facility automatically adjusts the initial stocks of people for the numbers of marriages, divorces, widowings, deaths, and migrant arrivals and departures during the year. Consequently, changes in the vital flows are directly reflected in changes in the age and marital status profile of the population.

Changes in population stocks and in their age and marital status profiles are likely to influence vital flows in later years. For example, a rise in the number of divorces at a given age will increase the number of divorced persons, and will therefore be likely to lead to an increase in the number of remarriages of divorced persons at a later date. In order to make an automatic allowance for the influence of changes in the population stocks on subsequent vital flows, the Population Projection Facility projects vital flows in terms of rates per numbers of persons at risk; for example, divorces are projected in relation to the numbers of married persons, while first marriages are projected in relation to the numbers of never married persons. Similar methods are used for all vital flows except migration (which is supplied as the net number of migrants). This formulation has the advantage of recognising the interdependencies between all the vital flows and between these flows and the populations which result.

3.2 Disaggregated Population Projections

The Population Projection Facility is designed to provide annual projections of the population disaggregated by sex, single years of age

Williams (1983c). Training courses have been arranged to enable policy analysts outside the IMPACT Project to generate their own projections.[19] Several illustrative projections have been reported (see Sams, Williams, Williams and Stevenson (1981), Sams and Williams (1982a), Sams and Williams (1983a) and (1983b), and Williams and Sams (1982)).

It must be emphasized that the role of the Projection Facility is not to supply just a single forecast or best estimate of the Australian population over some future period. Rather its purpose is to assist in policy analysis; that is, to enable the adoption of a systematic approach to quantifying the consequences for the size and structure of the population of different assumptions about economic and social conditions. Not only will the Facility provide specific population estimates for a range of settings of the exogenous variables, but it will also provide insights into the mechanisms linking changing economic conditions to the future level, composition and labour force participation of the Australian population. In the design of the computer software, care has been taken to maintain flexibility. Consequently, the Facility can be used at various levels of integration both internally and within the BACHUROO module. For example, we can foresee that further developments of the econometric models could be implemented without unduly disturbing the structure of the rest of the Facility. Likewise, we foresee linking the other BACHUROO submodules to the Facility without the need for major modification to the software.

In summary, the IMPACT Population Projection Facility is designed to provide consistent and strongly integrated annual projections of demographic variables such as age specific vital flows, births and

5. SUMMARY

The Population Projection Facility of the IMPACT medium term model provides projections of the Australian population, labour force and households by sex, age and marital status within a tightly integrated framework which respects demographic accounting identities and which faithfully tracks through time the effects of changes in the age and marital status profiles of the population, but which 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 which are amenable to econometric modelling and which, therefore, are available for forging links between demographic changes and wider economic influences. By allowing this technique to separate the effects of changes in behaviour from changes in the demographic structure of the population due to ageing and previous history, the Facility has simplified the task of the econometric models by limiting their role to capturing behavioural changes and not those arising from mechanical changes in population structure. An econometric model is available which may be used to relate decisions concerning marriage, divorce, fertility and labour force participation to each other and to economic and social variables. A further econometric model provides estimates of household headship rates and, when combined with the projected populations, provides projections of the number of households.

The Projection Facility has been established as an interactive suite of computer programs incorporating the features described in Sams and

(from 0 to 100+), and four marital states (never married, married, divorced and widowed). Data at this level of disaggregation are available from the Australian Demographic Databank[10] which provides annual estimates of the Australian population, and all the required marriages, divorces, widowings, births, deaths and migrant arrivals and departures necessary for consistent updating of population estimates from one year to the next, for the period 1921/22 to 1975/76[11].

The level of disaggregation available in the Databank has been maintained in the Facility for several reasons.

Firstly, the chosen level of disaggregation allows a greater flexibility in future uses of the Facility in that users can determine at a later stage the level of aggregation required for particular applications.

Secondly, it was considered desirable to take explicit account of the age dependence of demographic events, since shifts in the age of occurrence of events were thought to be an important characteristic of Australian demographic change.

Thirdly, an annual model is required for integration with the IMPACT medium term model.

Fourthly, the Facility maintains the disaggregation by single year of age since it is convenient to update the population projections by single years of age in a single year. (The subsequent problems of managing large amounts of data can be handled without difficulty by a technique to be discussed later.)

Fifthly, disaggregation by marital status, in particular, was maintained because several of the outputs of the BACHUROO module, such as the labour force and the number of households, are marital status dependent.[12]

Finally, the maintenance of a high level of disaggregation and the imposition of consistent and integrated cross-linkages between the demographic events in each year and the population at risk of each event enables a detailed explanation of the mechanisms underlying demographic change. This is because the degree of resolution achieved allows one to distinguish between different variables which figure importantly, but in different ways, in determining demographic change. It is the challenge facing the econometric models described in Section 4 to provide a behavioural basis for these mechanisms underlying demographic change.

3.3 The Integration of Disaggregated Vital Flows within this Framework

Ideally, the Population Projection Facility should maintain the level of disaggregation of information available in the Databank, but this would involve keeping track of an enormous flow of information which is more easily handled in a condensed form. The condensation technique used provides disaggregated projections of vital flows which respond to changes in the age and marital status profile of the population and which utilize a manageable number of interpretable descriptive statistics. These statistics are able to capture changes in the underlying determinants of demographic change and can be projected econometrically.

economic and social variables. The relationships within the model must be specified within a more rigorous microeconomic framework. Further developments to the econometric model are proposed to remove these weaknesses.

4.2 Household Formation

The econometric model of household formation determines sex, age and marital status specific household headship ratios on the basis of a set of variables which measure the ability of members of each demographic group to afford to form and maintain a separate household. The model was estimated with household data from the 1961, 1966, 1971 and 1976 Censuses and income and labour market data spanning the period 1961 to 1976. The model, details of which are given in Williams and Sams (1981), has been successful in explaining the evolution of household headship rates over the 1960's and 1970's and has also been used successfully for projection purposes (Williams and Sams (1982)).

demands for children can be manifest either as a change in the number of children or a change in the quality of their life. The demand for increasing quality with regard to children can influence both the rates of marriages and the number of women willing to participate in the labour force. Participation within the labour force can influence the demand for children and child quality. Married women can choose between work in the home, in the labour force, or leisure; the choice is modelled as being influenced by the opportunities, costs and benefits to be expected from each of these. Thus within the Facility, decisions concerning marriage, divorce and fertility are closely related to decisions affecting the supply of labour.

Further details of the current version of the econometric model can be found in Brooks, Sams and Williams (1982). The equations of the model are presented in that paper, where its performance in reproducing observed historical changes in demographic variables is assessed by the authors. Whilst this model was reasonably successful in describing Australian demographic change over the period 1921/22 to 1975/76, it has several weaknesses. Criticisms relating to the modelling of fertility have been mentioned above. Also, the labour force participation model is incomplete, as the rates for males are not modelled at all, whilst those for females are modelled at a very aggregate level (that is, for only three age groups and two marital states). To fully represent changes which have occurred, or are anticipated to occur in labour force behaviour, a model disaggregated by sex, eight age groups and two marital states would be preferable. Of more importance, the simple log-linear structure of the equations of the model, and its limited simultaneity between endogenous variables, does not enable it to capture adequately the complex relationships between demographic,

For first marriage, divorce and remarriage, the technique used approximates the age specific rates for each vital flow in each year by a smooth curve across the age distribution. This smooth curve, or model schedule, can be determined in each case by a few descriptive statistics.[13] For example, first marriages are calculated by approximating the proportion of first marriages to unmarried persons at each age by a smooth curve which rises steeply at young ages, peaks in the early twenty year old age group and then falls away slowly for older ages. The position and width of this smooth curve in any year is summarized by its mean and variance, and its scale is determined by a third statistic, which is named the propensity. When projected using econometric techniques, these three descriptive time dependent parameters - - in this case the mean age and variance of age at first marriage, plus the propensity to first marry - - allow individual rates of first marriage at each age to be reconstructed. All marital status changes are projected using the same approximating technique but with smooth curves appropriate to each.

To maintain consistency in the projection of marital status changes, it is necessary for each marriage or divorce of a woman (man) to result in a corresponding marriage or divorce of a man (woman). To this end, the Facility includes two-sex marriage and divorce models, documented in Sams (1981), which utilize historical information concerning the correlations between the ages of divorcing partners and between the ages of brides and grooms for each year.[14] Within the two-sex marriage model, a marriage selection rule determines the distribution of marriages according to the ages of each partner. While the male and female preferences for unions involving a woman and a man of given ages essentially are regarded as being

stationary, the allocation rules in the two-sex marriage model ensure that feasibility criteria are met. Thus the projected number of men of age (say) 26 marrying a woman aged (say) 24 is guaranteed to be equal to the number of women aged 24 marrying men aged 26. Total marriages of each sex at any age are also constrained so as not to exceed the available supplies of unmarried men and women. Similar feasibility constraints are enforced in the two-sex model of divorce. These procedures thus allow consistent projection of male and female marital status change and the construction and maintenance (via successive updating) of a cross-tabulation of married couples by the age of husband and wife. This ensures that the numbers of married men and women are equal, that events which influence one partner also affect the other, and allows the calculation of widowings directly from the deaths of spouses.

The above technique enables the Population Projection Facility to sustain a disaggregated level of projection for marriage, divorce and remarriage. However, this implies that the same level of disaggregation must be maintained for all other vital flows. The Facility does not attempt to model migration flows,[15] so migration data disaggregated by sex, age and marital status must be supplied by the user. In the current implementation of the Facility, full details on deaths are supplied externally; however, an approximating technique, based upon that of Heligman and Pollard (1979), has been developed in order to reduce the data requirements to a few descriptive parameters to be supplied by the user.[16] The need to supply disaggregated widowings statistics is avoided by calculating the widowings of women (men) as a consequence of the deaths of married men (women).

4. THE ECONOMETRIC MODELS

4.1 Fertility, Marriage, Divorce and Female Labour Force Participation

The econometric model of fertility, marriage, divorce and female labour force participation supplies a consistent description of marriage, divorce, fertility and labour force participation rates for women and the relationship of these to economic and social conditions. The model is described in detail in Brooks, Sams and Williams (1982). Currently, male labour force participation rates are supplied exogenously to the Facility.

The econometric model is grounded in a microeconomic approach which assumes that decisions concerning marriage, divorce, child bearing and labour force participation involve a strong component of economic rationality. The specification of the model derives from the new home economics and the Becker model of marriage, which applies the framework of constrained choice to the marriage decision.[18] The rates of marriage and divorce and the ages at which these occur are therefore modelled to be influenced by the costs and benefits of marriage and divorce respectively. In Section 3.4, we indicated that the treatment of births allows the decision to have children to be characterized as a sequential process in which first nuptial confinements and higher order births are modelled independently. This permits a distinction in the model between the decision to become parents and the subsequent decision on the total number of children to have. A distinction is also made between the desired number of children and the desired material quality of life for the children. Thus a change in the

fully capture both the demographic influences upon fertility and the sequential nature of decisions regarding fertility. In the meantime, users of the Facility may omit the econometric model of fertility and specify their own age specific confinement rates.

3.4 The Integration of Fertility within this Framework

Projections of fertility within the Facility can be made in either of two ways:

(i) using the econometric model of fertility, marriage, divorce and female labour force participation. This treats the decision to have children as a sequential process, in which the decision to have children at all (that is, to have a first nuptial confinement) and subsequent decisions to have additional children are treated separately. Given a chosen scenario of economic growth, the econometric model projects the first nuptial confinement rate, which is applied to the number of married women to derive the number of first order confinements, and the mean and variance of implied completed family size, which are used to calculate parity progression ratios (that is, the probability that a woman with a given number of previous confinements will have at least one further confinement).[17] These parity progression ratios can then be used to determine the numbers of second, third and higher order nuptial births in any given year. Ex-nuptial births are calculated simply as an exogenously determined proportion of the number of nuptial births;

(ii) using exogenously specified confinement rates disaggregated by age of the mother or by age and marital status of the mother. These confinement rates are applied to the appropriate populations of married and unmarried women of each age. The age specific nuptial confinement rates can be further disaggregated by birth order, but (as data on

married women are not available disaggregated by parity) these rates are applied to the total population of married women at each age. In the same manner as described for deaths, marriages and divorces, smooth approximations (model schedules) of the age specific confinement rates can be generated from a set of user-supplied parameters. Unlike marriage and divorce, however, there is currently no link between these parameters and an econometric model.

Details of the modelling of fertility within the Facility can be found in Sams and Williams (1983c). As explained there, the econometric model is unable fully to capture all of the important demographic influences on Australian fertility. In particular, it has limited success in tracking

(i) the number of women at risk of having a child;

(ii) the ages at which women have their children; and

(iii) the size distribution of families;

nor is the model able to relate these to the economic and social environment with any precision.

A major factor in accounting for this limited success of the econometric model is data related. Ideally parity progression ratios would be projected separately for all cohorts of women of child bearing age in any given year. This would avoid placing undue emphasis on current economic conditions in determining fertility behaviour, as the reactions by women in each cohort to current conditions would be conditioned by the previous

history of that cohort. Data preserving this amount of detail presuppose the existence of longitudinal fertility surveys which are neither available nor contemplated in Australia. However time series data on stocks of women by age and parity could be constructed fron currently available sources. Thus the representation of fertility within the Facility would be greatly improved by the following:

(i) the generation of an historical data series of the number of married women by age and parity;

(ii) the collection of an historical data series of age and birth order specific nuptial, and age specific ex-nuptial, confinement rates;

(iii) the estimation of an historical data series of model schedules for each of these age distributions of age specific confinement rates. In a similar manner to that discussed for marriage and divorce, the model schedules would be described by the propensity for, and mean and variance in the ages of, married women who are having their n^{th} child, and the propensity for, and the mean and variance in the ages of, mothers of ex-nuptial children; and

(iv) the specification and estimation of an econometric model which relates the parameters of these model schedules to the economic and social environment.

The current treatment of fertility in the Facility has weaknesses, but it does successfully capture some elements of sequential decision-making. With the improvements suggested above, the Facility could success-