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ENDOGENISING DEMOGRAPHIC VARIABLES IN

DEMO-ECONOMIC MODELS:

THE BACHUE EXPERIENCE

by

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I. Introduction

The purpose of this paper is to describe, discuss, and draw lessons from the treatment of behavioural demographic variables in the Bachue models. These variables are endogenous elements of a wider demo-economic system containing other components which are not described here. In particular, we do not discuss the endogenisation of those non-demographic variables which affect demographic behaviour. We instead concentrate on certain theoretical, technical and practical problems encountered in inserting demographic variables in the system as a whole; how they have been measured in the various applications of the Bachue models, how they are behaviourally explained and linked to the other elements of the system, the data sources used, and some issues of econometric estimates and modelling. The models considered here are those for the Philippines (described in Rodgers, Hopkins and Wéry, 1978), Kenya (a technical description is given in Anker and Knowles, 1980), Brazil (a summary description is available as Braganca, Burle de Figueiredo and Rato, 1980; see also IBGE, 1979) and Yugoslavia (described in outline in Macura, Popovic and Rasevic, 1977). Occasional reference is also made to a simplified international model (Moreland, 1978). A general description of all these models is given in ILO, 1979.

One objective of the paper is to draw from the Bachue applications general principles on the modelling of demographic variables in a demo-economic system. However, the diversity of the various models is such that generalisations are sometimes difficult to attain. This is particularly true of demographic variables measuring particular characteristics of the population, such as household formation and household categorisation, which are treated differently and in more or less detail from one model to another. But it is also true that the specifics of each country situation rule out many over-all conclusions - the optimal approach in Yugoslavia will evidently differ from that in Kenya. Thus in presenting the experience with different Bachue models, the stress is on illustrating and comparing the solving of particular problems, identifying difficulties, and discussing the advantages and disadvantages of particular paths to modelling objectives, rather than pursuing the mirage of a universally valid approach.

The demographic variables treated endogenously in the Bachue models are:

- i) fertility
- ii) mortality
- iii) migration
- iv) nuptiality
- v) household formation

Two "para-demographic" elements are also considered:

- vi) schooling
- vii) labour force participation

Fertility and mortality are the two basic components of population growth; migration is the third basic behavioural variable required for tracking a spatially disaggregated population. The four other variables have slightly different functions. They constitute criteria to further disaggregate the population according to categories relevant to the network of relationships between demographic and economic phenomena.

Nuptiality and/or marital status has a role in the determination of fertility, as well as in labour force participation and in household formation. Household formation, from which is derived the number of households and certain household characteristics, is needed because the household is a major agent of both economic and demographic behaviour. Schooling rates determine the education level of the population, and thereby influence the behaviour of individuals and households, with consequences for labour market mechanisms and for the generation of inequalities. The relevance of labour force participation in a Bachue model is obvious.

There is a difference in kind between these variables and the basic demographic variables of fertility, mortality and migration. Whereas the latter are fundamentally quantitative, schooling, labour supply and so on have important qualitative aspects, permitting for instance a distinction between illiterates and literates, or between "working" and "non-working" populations. These qualitative characteristics play an important role in the link between demographic and economic sub-systems, though the degree of reliance on variables such as these varies from one Bachue model to another.

The logic of the endogenisation of the demographic variables partly rests on the existence of feedbacks from these variables to the behaviour of the economic-demographic system as a whole. But it also depends on the hypothesis, established or assumed, that each of these variables is to some extent responsive to socio-economic change. These are empirical issues, and consequently the endogeneity of some of the demographic variables varies from one country model to another.

II. Population Accounting and Inter-temporal Structure

The core of the demographic sub-system consists in tracking the population over time. The primary disaggregation of population is by age and by sex, criteria which are present in most behavioural relationships, either explicitly or implicitly. Certain age classes are more likely to migrate, and migration can also be sex specific; schooling affects particular age groups; over-all fertility depends on the age structure of the female population; young entrants to the labour market are less likely to find a job easily; female school enrolment is less than for males, and so on. Population in the Bachue models is therefore sub-divided by age (5 year or single year groups) and by sex. The tracking of disaggregated population cohorts raises problems of data management, but it is in principle the simplest approach to obtaining population cohorts of a given age and sex at different points in time. Although techniques exist to describe population age and sex structure through distribution functions, the approximations which such functions involve are risky to introduce in a long term demo-economic system undergoing substantial changes. The same reasoning has also led to a break down of population both spatially and by education level - these two disaggregations corresponding to structural features of the economic sub-system - with the subpopulations so identified tracked over time.

The population accounting consists in tracking over time identified population cohorts broken down by age, sex, location, education level, and whether or not enrolled in school, with the possibility of extension to other dimensions. The term accounting is used by analogy with other accounting sub-systems found in the Bachue models, as distinct from behavioural sub-systems. The population accounting is essentially an elaborate cohort component projection method, establishing that population at time (t) is equal to population at time (t-x) plus births minus deaths plus net in-migration occurring during the period x, together with an adjustment which allows for changes in the other dimensions of disaggregation (school enrolments, drop-outs, etc.). Thus

$$P(t) = A(t-x) \cdot P(t-x)$$

The elements of matrix A are the subject of this paper. From the accounting point of view, they are fertility, survival, migration, enrolment, drop-out, labour force participation, nuptiality and headship rates, each broken down according to the basic disaggregation criteria: age, sex, location, education level. As such a complete accounting would entail very large matrices, and thereby entail heavy computing and data handling costs, certain simplified computation techniques are used.

With respect to the time period of the models, early work on a prototype Bachue used a "systems dynamics" approach (see Blandy and Wéry, 1973). The underlying structure of the model in this approach is a set of differential equations; the period of time in which such equations are solved is short relative to the simulation period as a whole, and so the changes which occur in model variables in one time period are small relative to total changes in a given simulation. This first model used as basic time period an exogenously modifiable fraction of one year, and Bachue-Philippines similarly is designed to permit different period lengths. In practice, however, it and subsequent models have tended to use one year as the basic time period.

Table I Accounting Characteristics/Period

	Brazil	Kenya	Philippines	Yugoslavia
Disaggregation of Population Cohorts	Five year age-groups up to age 65, sex, rural/urban, education level (4). No tracking of school population.	Single year up to age 65, sex, rural/urban, education level (3), whether enrolled or not. Separate tracking of school population allowing for repeating	Five-year age groups (except for 0,1-4 and 65+), sex, rural/urban, education level (3). Indirect estimation of school age population	Single year up to age 65, sex, region (8), A/NA, education level (3) whether enrolled or not. Direct tracking of school population.
Period	2.5 years period	One year period	One year period or less	One year period

Notes to tables I to VIII

- (*) A/NA agricultural and non-agricultural sectors (Yugoslavia).
 (A): agriculture consists of the private sector agriculture;
 (NA): non-agriculture includes all non-agricultural activities and social sector agriculture.
- (**) R/U Rural/urban areas
- (***) AE Adult equivalent
- (****) LFPR Labour force participation rates

In comparison with the 30 or 40 year simulation, changes during one year are small; indeed for some variables, given the magnitude of the change over such a period, it is arguable that a longer period will suffice. However, the shorter the period during which economic and demographic phenomena are observed, the less they appear to be simultaneous, and the less it is necessary to represent them as a simultaneous system. A recursive approach is desirable because it considerably eases computing problems and, more generally, permits the development of the model by blocks which are integrated sequentially. Balancing the different arguments, a one year period appears to be short enough to describe most phenomena considered in a long-term oriented model, in a recursive way, and long enough to avoid certain types of other short term (e.g. seasonal) relationships, and unnecessary computation.

The main exception to the use of a one year period in the Bachue models developed so far, is in the National model of Brazil (IBGE, 1979), where rigorous 5 years age group demographic projections have been used. This period is too long for economic simulation, however, so population variables are interpolated for every 2.5 years, and the economy is run on a 2.5 year period. This has proved to be rather cumbersome as a procedure for linking demographic and economic systems, and reduces the scope for adjustments and feedbacks, whereas the whole model is still recursive. It has therefore been abandoned in later developments of the Brazil model which revert to a one-year time period.

The fact that the basic time-period of the model (e.g., one year) does not correspond to the period during which a variable is measured or to which it refers (e.g. population broken down by five-year age groups), does not matter in the "systems dynamics" approach but leads to the introduction of unfamiliar notions. In Bachue-Philippines, the fraction of five-year age groups transferring to the next one during one year, is computed through a "maturation rate". More examples were found in Bachue I (Blandy and Wéry, 1973).

Another important factor to bear in mind is the diversity of lag lengths between different relationships in the model. For instance there is reasons to believe that the response of migration to socio-economic change will be faster than the response of fertility, but that both of these may be slower than the response of a purely economic phenomenon. If the overall recursivity of the model is retained, it follows that the period has to correspond to the shortest lag identified, so that the lag structure of the whole model can substantially differ from that of single period recursive models. Otherwise, relations involving a lag structure less than one period, have to be reconceptualised or incorporated through econometric approximations (e.g. lag structure between household consumption and income). This problem of "distributed" lags has not received the attention it deserves in the Bachue modelling, mostly because existing data do not permit the estimation of complex distributed lag sub-models. Indeed processes known to be recursive, such as many demographic phenomena, have had to be estimated on cross-sectional data.

III. Fertility

(i) Measurement of Fertility

The measure of fertility used as a dependent variable in the various Bachue models differs considerably between applications. Given that the population is broken down by age and sex, the measure of fertility which is most consistent with this structure is age specific fertility rates. Such rates already allow through their disaggregation for one of the factors, i.e., changes in age structure, which are frequently recorded as responsible for changing over-all fertility levels. If age specific marital fertility rates are used, changes in age at marriage are also taken into account.

However, more aggregated measures have been used as the dependent variable in certain modelling applications. For instance the Philippine model uses the gross reproduction rate, while the Brazilian model uses three age specific fertility rates. In both cases the complete set of age specific rates is computed assuming a particular age pattern of fertility. Clearly some information is lost in these approximations; in particular when using synthetic fertility indices, certain components of aggregate fertility are lost (mortality pattern in the GRR, nuptiality pattern if the index is computed on the whole female population). This problem can be partly dealt with by using behavioural functions in which the synthetic index is one explanatory variable of age specific marital fertility rates.

An interesting alternative procedure is to treat the parameters of a fertility distribution function as dependent variables (A.J. Coale, 1971). This approach, which is analogous to the derivation of age specific mortality rates from life expectancy at birth using life tables, has been applied in Bachue Yugoslavia. The procedure avoids the estimation of age specific behavioural equations, but of course depends on the hypothesis that the distribution function correctly describes behaviour.

(ii) Explanatory Variables

Endogenisation of fertility in an economic-demographic model of the Bachue type is largely based on a theory of household behaviour. Fertility is regarded as resulting from a conscious decision, which takes into account the quantitative advantages and disadvantages of child-bearing. Such an approach can be seen in the utility maximisation framework of the "new home economics", though this is not necessary, since most of the implications of the former can be derived from simpler analyses. Socio-economic characteristics of the household are seen in this framework as major determinants of its fertility behaviour. Important variables include the education level of the mother and father, the mother's past and present economic activity, household income, child mortality, and the education or desired education of children. The gains from child-bearing also depend on the foreseen economic activities of children, and the extent to which parents benefit from these activities. A considerable literature exists on the precise specification of models of this type.

Table II Fertility

	Brazil	Kenya	Philippines	Yugoslavia
Dependent Variable	Average of fertility rates for age groups 20-24, 25-29, 30-34. Specific age rates derived from predetermined fertility patterns by R/U corresponding to dependent variable values	Total fertility rate R/U, mapped onto age specific fertility rate through fixed R/U age patterns.	Gross reproduction rate R/U mapped onto age specific marital fertility rates used to compute actual number of births.	M & m parameters of Coale's marital fertility model, A/NA, mapped onto specific rates by region, A/NA through Coale's function. Age specific extramarital fertility rates by region, A/NA
Explanatory Variables	% literates, % active population in secondary activities, % women aged 15-49.	Sterility (endogenous), female education, mortality (survival rate to age 3), migrant status (urban), household income per AE. Other explanatory variables not retained in model equation (eg. polygamy, breast-feeding). Land size and husband's education proxied by household income.	% active population in agriculture, % illiterates, % active women. life expectancy at birth	Female education and LFPR child schooling, marriage instability, family planning service regional dummies, male education (for NA), land size (for NA). Extramarital fertility rates constant.
Comments	Linear specification. International cross section. Adjustment of intercept to national R/U value of dependent variable.	Linear specification except for female education. National household survey data. Sterility effect derived from an analysis on Kenya district level data.	Linear specification International cross section. Adjustment of intercept on R/U GRR	Linear specification except for m/NA log-linear. Population census, vital statistics and socio-economic aggregates data for 79 demographic regions. Adjustment of intercepts and dummies to region and A/NA observations.

The explanation of fertility behaviour is therefore essentially micro-economic. Such an approach does not normally capture variables such as norms, tastes, psychological factors, values, etc; nor are structural socio-economic relationships such as patterns of class behaviour allowed for. The reason for not considering such elements in fertility behaviour is not so much that micro-economic theory and other theories have not been linked together, or even that they conflict with each other, but mostly because of the way data are usually collected. Household surveys rarely gather, at the same time, information at a higher level of aggregation, and it is not always easy to link aggregate data from other sources with household survey data. In practice, therefore, the micro-relationships are necessarily treated for modelling purposes, as estimates of the corresponding macro relationships, which means that the omission of some, at least, of these more aggregated variables is particularly unfortunate.

The method of estimation of micro-relationships affects the sensitivity of the functions concerned. For instance, when household surveys are used, national or cross-sectional variations in fertility behaviour might be small, relative to changes over time, because of the tendency for fertility patterns to cluster around the norm, and for large deviations from this norm to have a considerable random component. As a result only small variations in fertility are explained in a cross-section function. By contrast, when a fertility function is estimated on the basis of aggregated data, pooled cross-sections or international cross-section data, clear distinctions between relatively homogenous groups will tend to be associated with fertility differentials, and explanatory variables will be more of a structural nature. This will tend to be reflected in a more sensitive fertility function.¹ The choice of specification therefore finally relies as much on hunch and intuition as it does on econometric refinement.

(iii) Calibration

Whether the fertility function is based on household survey or on more aggregated data, the level of fertility in the model has to be consistent with national observed values. This has implications not only for parameter estimation, but also for the conceptualisation and definition of explanatory variables. For instance, highly aggregated cross-section relationships may involve variables, such as the proportion of the population which is agricultural, which may have no particular meaning for some sub-populations in the model (e.g., if there are no agricultural activities in urban areas). The calibration of the

¹ It does not follow that international cross sections should be preferred to less aggregated types of data sources or analysis. Indeed even if macro relationships offer advantages, too high a level of aggregation is often associated with a rather confused and simplistic identification of structural factors and it then becomes difficult to find the equivalent of these factors in a national model. And while a higher level of aggregation allows the introduction of structural determinants of fertility, the interpretation of the macro-equivalents of micro-relationships is often difficult. For instance, household fertility at the micro level may be determined by past and present activity of the wife, but the effect of aggregate female labour force participation rates on aggregate fertility may reflect quite different mechanisms. However, it may be noted that in Kenya, analysis of fertility differentials using both micro (household) and macro (district) level data gave similar over-all predictive results.

estimated function to the observed situation proceeds in general on the assumption that differences between observed and predicted outcomes are due to characteristics specific to the country, and not to the relationship with the explanatory variables; that is, the intercept is adjusted rather than the parameter.

This is just one aspect of the broader problem of adapting a general model to a given situation. In each Bachue application there is an ad hoc treatment of this problem which attempts to take into account the characteristics of the function and of the country concerned. In the example above, which is taken from the Philippine application, the proportion of the population which is engaged in agriculture is regarded as representing structural economic factors, rather than a specifically agricultural behaviour pattern, and the variable is therefore utilised to explain fertility in urban areas, taking the same value as in rural areas.

(iv) Family Planning

A particularly important and controversial aspect of the determination of fertility is the role of family planning programmes. In general it seems likely that the acceptance of family planning and individual fertility decisions are jointly determined, making simple attempts to explain fertility as a function of the acceptance of family planning unreliable. Although there exists some empirical work which separates out the effects of family planning, the results obtained must be regarded as experimental. For modelling purposes the impact of family planning programmes has been incorporated through an exogenous decline in fertility during model simulations, except in the Yugoslavia application. In this model, marital fertility levels are explained, among other socio-economic variables, by the number of married women per medical doctor specialising in gynaecology or obstetrics, regarded as a proxy for the availability of induced abortion services, if not of other family planning methods.

IV. Mortality

(i) Measure of Mortality

The representation of mortality in the Bachue applications uses the normal procedure of demographic projections: a synthetic index such as life expectancy at birth, or the probability of a birth surviving to age three, is projected and used to recompute the components of the index, i.e. the age specific survival rates. The accuracy of the mapping of the overall index on to age specific rates varies. In the Brazil model, national life tables were constructed whereas in the Philippine and Kenyan models standard Coale-Demeny life tables were used. In Yugoslavia the relationship between mortality patterns below and above 5 years of age was found to be poorly represented in model life tables. Life expectancy at age five did not vary much between regions, and future mortality declines were unlikely to be large; this was not the case for ages 0-5. Therefore, these two age groups have been treated independently and each used to locate its corresponding segment in the model life tables. Moreover only child mortality has been endogenised.

Sex differences are allowed for in this approach, in so far as mortality rates differ between males and females, and also in so far as life expectancy at a particular point in time is differentiated by sex. It has in general been assumed that the initial male/female differences in life expectancy will remain constant over time or that they are adequately represented by the patterns in model life tables. These are rather crude assumptions, particularly in countries where female life expectancy is less than male life expectancy, a difference which no doubt reflects socio-economic rather than biological factors and which is therefore likely to change.

(ii) Explanatory Variables

With the exception of the Kenyan model, where a fuller endogenisation was attempted, mortality has only been explained by aggregate socio-economic variables without taking into account the factors directly affecting the health of individuals. The main reason for this is that the latter effects are difficult to assess, except where major endemic diseases exist. Rather than identifying the immediate causes of survival, therefore, the explanation of mortality has been couched in terms of socio-economic correlates. Low levels of mortality are found in higher income countries, and are associated with extensive medical infrastructure, with urbanisation and with higher educational levels. The distribution of the population with respect to these variables, and the degree of non-linearity in the relationships concerned, are also important.

This approach raises a serious issue in policy modelling; that is, since the direct effects of health programmes on health are difficult to observe, their impact in the model has to be allowed for through exogenous changes in the dependent variable rather than through the manipulation of independent policy instruments. For example, it would not be possible to assess the impact in the model of water supply programmes or the provision of intermediate level medical services, unless the impact of the programmes on health is already quantified. The problem is similar to that raised by the exogenous way in which the impact of family planning on fertility is represented. This lack of endogeneity of policy measures is unfortunate because, while long term trends in mortality are clearly associated with long term socio-economic changes, specific programmes certainly have an impact in the short term.

The implications for data and estimation of an attempt to resolve the problems in estimating mortality functions would point in the direction of matched samples in controlled experiments. In practice, however, one is usually forced to instead use aggregated national or international cross-sections which can at least give some indication of the correlations of mortality levels with socio-economic differentials.

In Kenya, a comprehensive household survey was used to identify the determinants of sex-specific survival probability up to age three. Variables of direct interest to health programmes such as access to piped water, the availability of health infrastructure, and the prevalence of endemic disease were included in addition to socio-economic characteristics of the household such as education level, income, and housing conditions. However a simplified equation has been retained in the model with an exogenous trend accounting for all policy-related variables.

Table III Mortality

	Brazil	Kenya	Philippines	Yugoslavia
Dependent Variable	Male life expectancy at birth. Constant ratio between male and female life expectancies. National life table used to derive survival rates by age and sex.	Survival probability up to age 3, R/U. Life expectancy at birth function of age 3 survival probability. Coale and Demeny North model life table used to derive survival rates by age and sex.	Life expectancy at birth Coale and Demeny West model life table used to derive survival rates by age and sex	Infant mortality (< 5 years), A/NA. Life expectancy at age 5 by sex, region and A/NA Coale and Demeny East model life table used to derive survival rate corresponding to each dependent variable.
Explanatory Variables	% literates 15+, % actives in primary and secondary sector, Gini coefficient.	Household income per AE, woman's education, time trend. Other micro & macro explanatory variables (eg. access to piped water, sex of child, endemic malaria) dropped in model equation and effects proxied by time trend and income.	Income, income distribution.	Life expectancy at age 5 exogenous. Female education, % illegitimate births, % births occurring to young and old mothers, regional dummies, land size & female LFPR for (A).
Comments	Linear specification. International cross section. Adjustment of intercept to R/U life expectancies.	Linear specification except for income. National household survey & survival of individual births data. Adjustment of intercept to R/U life expectancies. Micro explanation on individual data used to derive time trend value.	Non-linear specification International cross section. Adjustment of intercept to R/U life expectancies.	Linear specification. Population census, vital statistics and socio-economic aggregate data for 79 demographic regions. Adjustment of intercepts and dummies to regional and A/NA observations.

V. Migration

(i) Dependent Variables

There are various migration flows which can be identified and which are represented in the Bachue models. A first disaggregation is between external (international) migration, and internal migration. Among the latter flows, one may distinguish intra and inter-regional migration, the nature of which will of course vary with different definitions of regions. Mobility between economic sectors may also involve physical movement of individuals, and this type of economically-based disaggregation will lead to a classification of migration which differs from that based on regions.

International migration is included in the Bachue models only where major flows can be identified. In the Philippines for instance, emigration of educated urban Filipinos is allowed for. In Yugoslavia, both emigration and return migration (and the associated financial flows) are incorporated in the model.

Internal migration between regions is treated in much greater depth in all models. Where the regions are rural-urban, this type of migration covers both geographical movement and, usually, sectoral labour mobility, in particular out of agriculture. In the Yugoslav case, where the rural region is identified with private agriculture, migration necessarily implies sector mobility. In other models, rural out-migrants are usually, but not uniformly agricultural in origin. In addition to a rural-urban disaggregation, the Yugoslav model is divided into 8 administrative regions. Current development of the Brazilian model also includes its disaggregation into 5 geographically specified submodels. In the Yugoslav application there is also a significant contribution of the rural population to urban production, through a commuting phenomenon, which then constitutes another type of spatial migration. In none of these models, however, are seasonal and short term migration explicitly considered, as the models are oriented to the long term.

Intra-regional movements are considered in an economic rather than a spatial sense. For instance sectoral mobility between different labour categories is possible, and this type of mobility is an important characteristic of the development process. However the geographical distribution of population is not modelled to the same level of detail - for instance, the distribution by size of cities is not considered. A related problem which needs to be taken into account is that rural-urban spatial distinctions change over time; that is, areas which are originally rural may become urban because of the natural growth of their population. Changes in behaviour of the population concerned can expect to be associated with this process.

Internal migration flows can be treated either as gross or as net. There is however a significant advantage from treating them as gross as the determinants of migration in different directions are not necessarily symmetrical. This is particularly true of rural-urban migration as compared with urban-rural.

Migration flows in the models are disaggregated by age, sex and education and sometimes by marital status. The measurement and simulation of these flows

raise no serious problems in principle: a given population has a certain probability to migrate in a particular time interval. However, while the identification of migrants at the origin is relatively easy, the distinction between migrants and non-migrants in destination populations raises certain problems. Conceptually it is easy to keep track of migrants, but in practice it is cumbersome to introduce a supplementary dimension in the population cohorts. Besides, the length of residence of migrants has significant behavioural implications, as there is a presumption that migrants gradually adapt themselves to urban conditions. None of the models tracks the migrant population separately from native cohorts. On the other hand, the proportion of migrants, which can be estimated separately, is sometimes considered, either to explain remittances to areas of origin, or to explain the current pattern of urban behaviour, including fertility.

(ii) Independent Variables

While behavioural factors of course enter into the determination of international migration, there is much greater scope for physical controls than is the case with internal migration. It is therefore reasonable to treat international migration as exogenous. Internal migration, on the other hand, is seen in all the Bachue models as an adjustment mechanism redistributing a factor of production according to the relative advantages of regions of origin and destination, though the outcome is by no means equilibrium, or even necessarily a movement towards one. Certain groups of the population are more sensitive to changes in relative socio-economic conditions than others, and so there needs to be a careful disaggregation of the migration relationship. But in all models the basic explanation is in terms of a balance between push and pull factors.

Migration is treated as a decision by an individual or a household, resulting from the comparison of present and possible future economic conditions in the place of current residence, and those in other regions. The income differential between regions is usually the main explanatory variable. A number of different variables are introduced to represent expectations: the unemployment rate and the inequality of income distribution are two of these. There are different classes of migrants, in part corresponding to particular segments of the labour market. Unskilled migrants, for instance, may be concerned exclusively with the possibility of finding a job in traditional/informal sectors and with the income they can expect in such a job; women will take account of the availability of "female" jobs; and so on. The propensity to migrate may also differ according to sex, age, education, marital status, and family situation.

While this approach to migration is common to all the models in the Bachue family, the nature of the migration process is country specific. Even if the explanatory variables are similar in different countries, their measurement, their conceptualisation and their quantitative evaluation, are likely to vary considerably. The implication is that migration functions need to be specified and estimated on the basis of national data; international cross-section relationships are likely to be particularly unreliable. The main differences in specification from model to model concerns the way individual characteristics and environmental factors have been treated. In some cases these have been built

into the same function (Brazil, Yugoslavia); in others (Kenya, Philippines) two separate functions have been estimated, one explaining the determinants of aggregate migratory flows, and the other determining the probability that an individual will migrate, given the over-all flow.

Data on migration detailed enough to allow functions of this latter type to be estimated, are only available from household surveys. These provide both time series (recall) data, which may be more or less complete, and which provide some information on the economic condition before migration, and cross-sectional information. Even so, it is often difficult to consider historical and structural factors. In addition, temporary factors with a large but unascertained influence on migration are difficult to isolate out. Among problems encountered, notice can be taken of the insufficient description of the household's socio-economic environment (e.g. land structure), and the fact that certain macro-level factors which are expected to affect migration, are measured after migration whereas migration rates can influence them (e.g. employment structure, unemployment rate). Moreover, many public policies such as land reform, introduction of new crops in certain regions, rural public work programmes, or physical controls (often of temporary or variable nature), can hardly be assessed without longitudinal surveys. There are thus some factors which limit the validity of the explanation of migration followed in the Bachue models. In particular the inadequate representation of structural factors suggests a direction for improvement.

VI. Nuptiality

Nuptiality is an important variable of the demographic system in at least three ways. Firstly, it has close links with fertility (to the extent that all births take place within marriage, it determines, in combination with marital fertility, the level and age pattern of over-all fertility). Secondly, the economic activity of married women tends to differ considerably from the activities of unmarried women. Thirdly, marriage is a component of household formation. However, the treatment of nuptiality in the Bachue models varies much more than is the case for fertility, mortality and migration. Actually, nuptiality is only explicitly considered in Bachue- Philippines and Yugoslavia, where legal marriage is traditionally the only form of union which leads to child bearing. In Brazil where consensual union is frequent, it might be expected that behaviour is different in the two types of union. As data and programme size did not permit this level of detail, nuptiality does not appear in the national model.

The application to Yugoslavia is the only model where divorce and widowhood is considered. This is important where a large number of unions end prematurely and therefore affect fertility. However, these two events are not explained endogenously in the model. This is a case where it was felt necessary to take into account the effect of an additional variable on an endogenous element of the system, though it is not possible to endogenise it.

Table IV Migration

	Brazil	Kenya	Philippines	Yugoslavia
External	None	None	Policy variable for some age-education groups	Permanent out-migration rates by age, sex, education and regions: policy variable. Temporary out-migration and return migration rates of workers and dependents by age, sex, education, region, A/NA: policy variable.
Internal				
Dependent Variables	Urban household head's probability to come from rural areas (no sex distinction).	Overall net R/U migration rate. Age, sex, education specific net migration probabilities derived from overall migration rate using fixed relative rates	Gross migration probability (micro) by sex between R/U & gross migration propensity (macro) by sex between disaggregate R/U areas. Gross migration rate combines both dep. variables multiplicatively with population weighting factor. Male and female rates assumed to be equal in simulation.	Gross migration rates from region i to A/NA sector of region j, by age, sex, education. Net migration rates out of (A) by age, sex, region. Inexistence of certain types of flows between and within regions of A/NA populations, assumed because of over-determination.
Explanatory Variables	Income differentials between regions, education, number of children, age.	Micro: education level Macro: household income per AE differentials; R/U modern sector wage rate & employment probability.	Micro: age, education level, marital status Macro: Income differentials, income distribution, R/U.	For inter-regional flow to NA sector: average wage, job creation rate, unemployment & female LFPR differentials, % women married in i, regional dummies. For inter-regional flow to (A) sector: land size, differentials, % women married in i, regional dummies. For net out-migration: NA average wage, job creation rates, unemployment and female LFPR, % women married and land size in i, regional dummies

Continued/....

Comments

Logit estimation.
Household survey and
population census data.
Adjustment of overall
migration rate to cen-
sus figure.

Bi-log overall rate func-
tion based on district
level data. Non-linear
functions for relative
rates derived from
national household sur-
vey. Return migration to
rural areas allowed.

Linear specifications.
Most explanatory vari-
ables are education and
often age-sex specific
Child rates (below 15)
function of childbear-
ing age female rates.
Population census and
socio-economic aggre-
gate data for 79 demo-
graphic regions. Adjust-
ment of intercept &
dummies to region and
A/NA observations.

Table V Nuptiality

Brazil

Dependent
Variables

Not explained.

Kenya

Not explained.

Philippines

Average age at marriage
R/U. Ever married
women distribution by
age derived from
Coale's function keep-
ing earliest age at
marriage constant.

Yugoslavia

Parameters of Coale's
first marriage model:
earliest age, pace of
union, % ever married,
A/NA. Widowhood,
divorce rates by
regions, A/NA.

Explanatory
Variables

Education. LFPR before
marriage.

Female school attend-
ance, female & male
LFPR, sex ratios, re-
gional dummies.

Comments

Linear function based
on individual data
from national household
survey. Adjustment of
ever married distribu-
tion to R/U observa-
tions.

Linear specification.
population census aggre-
gate data for 79 demo-
graphic regions.
Intercepts and dummies
adjusted region & A/NA
values of dependent
variables.

(i) Dependent Variables

The dependent variables can either be the proportion of married women in each age group, or, more commonly, the parameters of a function which determines the distribution of married women by age group, a procedure followed in both models which consider nuptiality. There are relatively few comparative studies of the latter distribution, and those which have been carried out have tended to use a distribution function developed by Coale (1971). This function has three parameters, and hypotheses with respect to the determinants of each are required - i.e., these or some parameters become the dependent variables.¹ Not all the parameters are necessarily explained within the models - in the Philippine case, only one of these is endogenous.

(ii) Explanatory Variables

In a "new home economics" model, the decision to marry would be regarded as a rational decision based mainly on economic factors. In particular the education of the woman is likely to delay marriage, because schooling raises the opportunity cost of marriage, while at the same time reducing its benefits because more educated women are potentially economically more independent. Similar patterns of relationships can be observed between economic activity and marriage patterns, in that the work of girls and young women raises the returns to the family of origin, which therefore has an interest in delaying marriage. It is difficult to translate this model directly into the explanation of parameters of the distribution function, but approximations can be made.

Of course only economists could think that the decision to marry is basically an economic one. Norms, tastes and culture also intervene, indeed are arguably dominant. One consequence is to make international comparative analysis of the age at marriage almost meaningless, because the content and functions of marriage vary so much between countries. Unfortunately, most of these non-economic factors are difficult to analyse quantitatively, so that in practice determinants of marriage rates tend to be based exclusively on the more readily measureable variables such as education and labour force activity.

VII. Households

Under this heading we include three issues: determining the number of households, their demographic characteristics in terms of size and age distribution of their members, and their socio-economic characteristics. There are conceptual problems in treating households as integrated units with definite boundaries, but we look to others for advances with respect to conceptualisation (Oppong, 1979) and set the problem on one side here.

¹ The transposition of Coale's function, which is specific to a cohort, to cross-section behaviour can raise inconsistencies in implicit cohort evolution over time. This can be avoided by keeping some parameters constant.

(i) Number of Households

The number of households is obtained in those Bachue models where households are included (they are not in Yugoslavia), from headship rates, applied to populations possibly disaggregated by variables such as sex, age group and education. The age and sex criteria are obvious; education level is also associated with different patterns of headship rates. Another relevant factor is marriage rates. The link between household formation and the marital status of women is direct only in pure nuclear household types. In the majority of situations where marriage and household formation are distinct demographic phenomena, different explanatory relationships are required. However, at an aggregate level, they are not independent. A change in the age at marriage with constant headship rates would imply a change in the composition of households. For instance, a lower age at marriage with a constant number of households would tend to be associated with a larger number of complex extended families.

Little quantitative evidence exists on these various relationships. The little empirical work which has been done, mostly using population censuses, indicates that there are sizeable variations in headship rates between different levels of development, but also between cultures and between countries with different demographic characteristics. Only one model endogenises headship rates, that for Kenya, where the rates (specific to women aged 20-59) are made a function of the adult sex ratio. In other models group-specific headship rates are kept constant.

(ii) Demographic Composition of Households

A number of aspects of economic behaviour depend on the size and age structure of households, including household consumption patterns, the participation of individuals in economic activities, and fertility (influenced by the parity level, sex ratio of children and the presence or absence in the household of people able to take care of children). In many cases, household income is also relevant, but these examples show the need to include demographic variables as well. In fact we would argue that the treatment of households is one of the most important issues in analysing economic-demographic interactions, in that it acts as a link between a number of different sub-systems. Nevertheless, little work has been done in this field, and the explanation of household formation and demographic characteristics is therefore relatively crude in the Bachue models. For instance, marriage and household formation are generally treated as independent of each other, which as noted above, does some violence to the facts.

The treatment of household composition in the Bachue-Philippines and Kenya models is the most elaborate among the models considered here. Both models start with an initial distribution of households by income group and demographic composition (size and age structure). In the former application, the implied headship rates are maintained constant over time, while changes in the size and composition of households by income group are assumed to be directly determined by changes in the age distribution of the population concerned as a whole and the average size of households. Thus demographic change is assumed to affect all types of household similarly (as noted below, different sub-groups are identified).

Table VI Household Formation and Socio-Economic Characteristics

	Brazil	Kenya	Philippines	Yugoslavia
Dependent variables	Aggregate headship rate R/U and sector specific (no age or sex distinction).	No. of females 20 and above per household, R/U. Average household size by income deciles R/U. Proportion of rural household in total.	Headship rates by age, sex, R/U(**) (HR). Average no. of children and adults by household income deciles, R/U(SIZ) R/U distribution of household heads by socio-economic status (HS). R/U average no. of active non-heads by socio-economic categories of heads (N). R/U distribution of non-heads by socio-economic categories (NS).	Not explained
Explanatory Variables	Sectoral distribution of total labour force, mean household income.	Household structure function of male/female ratio for ages 20-59. Household size function of household income. Proportion of rural households owning land, function of population pressure.	(HR) constant. (SIZ, HS, N & NS) variables change in proportion to changes of their respective aggregates, eg. HS=f (total employment distribution)	
Comments		Macro district level data. Adjustment to R/U (**) population census figures.	Micro and aggregated data from national household survey.	

This is in contradiction with the micro-theory of fertility behaviour, in which the nature of the household will influence the fertility pattern. Changes in socio-economic conditions should therefore act on fertility in a way which is differentiated by household type, so that differential changes in age-sex structure will occur. Strict proportionality of changes is therefore likely to be a rather poor assumption and work to improve this approach would be desirable, for instance developing further the link introduced in Bachue-Kenya, between the size distribution and income distribution of households.

(iii) Other Classifications

Income is not the only criterion for the classification of households. Another important classification in certain applications of the Bachue models is the distribution of households according to the employment status of the head. Here again the initial conditions are easily determined, but the evolution over time can be complex. In Bachue- Philippines and Kenya, where these issues are treated in more detail than in other models, the occupational distribution of household heads is known at the origin, and is assumed to change proportionally with the over-all occupational distribution of employment. Thus a decrease in over-all agricultural employment implies a decrease in the number of agricultural households.¹

Associated with the occupational distribution of household heads, the distribution of non-heads according to the head's occupation is also required for household income distribution purposes. This gives rise to a matrix of the distribution of non-head activities according to the activity of the head. The coefficients of this matrix have to change over time with changes in the employment structure of the population, with the sectoral distribution of production, and so on. Fairly mechanical methods have been used in this process to date. One can foresee important behavioural relationships which such an approach omits. To treat them adequately, however, would require disaggregating the matrix concerned by so many criteria that it would lead to impossible data and computing requirements.

In an appendix we present some thoughts on possible improvements in tracking the demographic and socio-economic characteristics of households, though we are far from solving all the problems involved.

VIII. Labour Force Participation

(i) Dependent Variable

The measurement of the labour force for modelling purposes raises a host of conceptual problems, discussed in some detail in Standing (1978). The use of inappropriate labour force concepts not only means that the measurement of labour supply is inexact, but also can seriously affect the behaviour of the labour market sub-system. For instance, neglecting to differentiate labour demand

¹ This is likely to be a less than perfect assumption because the out-migration of members of agricultural households will lead, in general, to a faster decline in agricultural employment than in the number of agricultural households. But it is better than to assume say, a constant distribution.

between male and female workers, and between different age groups (as is indeed the case in all the Bachue applications except for the forthcoming regionalised application to Brazil) is likely to produce some misleading results. Care is therefore required and there may be a case for incorporating several alternative definitions of labour supply (although this has not been done in any model so far).

For modelling purposes, it often appears that certain categories - notably adult males - have labour force participation rates which are very similar across widely varying socio-economic conditions, and can therefore reasonably be treated as exogenous. Endogeneity is more important for the category of "secondary workers", i.e., principally women and youths, where much greater variation is observed.

(ii) Determinants

The determinants of labour force participation include elements of household economics, demographic characteristics of the individuals and labour market conditions. A typical equation would explain labour force participation, disaggregated by sex and age, as a function of the education level, marital status, the number of children or the age of the youngest child, position in the household, household head's occupation, industrial structure, minimum wage for a given education or skill level, household income, unemployment and the rate of job creation (see Standing 1978, and Standing and Sheehan, 1978).

In the Bachue models, cross sectional household survey data have usually been used to estimate such equations, sometimes aggregated at the regional level. The use of such data may restrict the inclusion of market related variables such as industrial structure, previous labour absorption, or the unemployment and wage rates, because there is likely to be insufficient variation in the sample or because these variables have just not been measured in the survey. In consequence many studies of labour force participation in developing countries omit demand factors. In the Brazilian model, this omission was considered sufficiently serious that labour force participation rates are determined by long term trends rather than by a participation function. At the other extreme, in both the Yugoslav and Kenyan applications, market variables have received much attention in specifying participation functions.

One consequence of the absence of demand factors in some of the models in explaining labour force participation rates is that they tend to be too insensitive to market changes, causing instabilities elsewhere. On the whole, instability due to specification error is not a major problem in large and highly endogenous economic-demographic modelling. Behavioural equations in such models generate a series of feedback mechanisms which allow the system to perpetuate itself or to smoothly change in the direction of market or social pressures. In the case of labour force participation equations, however, changes on the demand side have an impact primarily on work and incomes rather than on the size of the labour force and unemployment, making wages relatively unstable. This can be partly overcome if an income variable is incorporated as a determinant of labour force participation, though it is not always obvious to what extent the cross-

Table VII Labour Force Participation Rates (LFPR)

	Brazil	Kenya	Philippines	Yugoslavia
Dependent variables	LFPR by large age-groups sex, rural/urban.	LFPR by age, sex, R/U of population not enrolled in school.	LFPR by age, sex, R/U, marital status for women, head/non-head for males.	LFPR by age, sex, education level.
Explanatory Variables	% migrants, % household heads, income by education level, education level, age.	Female education, household income per AE, husband absent, % employed in services, % unemployed & in traditional sector, modern service wage (other micro and macro variables not retained in model equation: eg. marital status). Male LFPR constant (for those not in school).	Household income distribution, education level, head's sector, age of youngest child (for married women), % modern jobs, % presently attending school. Male head LFPR is constant.	Male LFPR's exogenous. For NA LFPR's: male & female education, employment growth, unemployment, % female married child second-ary education, regional dummies. For A LFPR's: marital fertility, sex ratios, child second-ary education, regional dummies.
Comments	Linear specification. This function is however not included in the present version of the model, which has constant LFPRs in groups defined by age, sex, R/U and education level.	Linear specification except for female education. Specification varies between urban and rural areas. Micro household survey data. Redefinition of some explanatory variables required for simulation purposes (eg. land size proxied by income). Proportional adjustment of intercept to estimated age, sex and R/U LFPR's.	Linear and inverse specification. Data: individual data from national household survey. Proportional adjustment of intercepts to aggregate labour supplies.	Linear specification. Population census, vital statistics and socioeconomic aggregate data for 79 demographic regions. Adjustment of intercepts and dummies to region, A/NA, age, education rates of dependents. For NA equations most explanatory variables are education specific.

section relationship estimated will adequately reflect changes as incomes rise over time. There are indeed reasons to believe that income, as a determinant of labour force participation, should be expressed in relative rather than absolute terms.

IX. Education and Skill

(i) Dependent Variable

Education is one of the basic criteria used to disaggregate the population. By education is usually meant the grade completed or the level obtained, irrespective of the number of years spent in school. However, in all applications of the Bachue models, except to Kenya, the number of years of schooling and the grade obtained are equivalent, as no repeating of grades is allowed for.

Education is assumed to be exclusively obtained in the formal sector and only includes certain ages of the population. Adult education programmes have not been included in any of the models so far.

Education levels are important direct explanatory variables of all demographic events, and either education or skill is also an important factor in labour market behaviour. In the labour market a distinction between education on the one hand and skill on the other is needed. In analysing labour force participation, the education level, as measured by the grade or number of years of schooling, is normally regarded as an important determinant. But at the same time as explaining behaviour, education levels also determine the credentials of the labour force, which in turn affect access to jobs. On the side of labour demand it is usually assumed that entrepreneurs require a certain skill for production purposes. Workers are recruited on the basis of educational credentials on the assumption that this provides the basis for skill formation. A strict correspondence between education and skill is therefore assumed in all the Bachue models.

(ii) Determinants of Education Levels

The education level of the population is usually determined by tracking school age children through the education system in a manner similar to the tracking of population cohorts through their life cycle. The dynamic behaviour of the system is therefore determined by transition probabilities from level to level, which in turn depend on enrolment, completion, drop out and (in Bachue-Kenya) repetition rates. Such rates have been shown to be a function of the education facilities available, certain specific government policies with respect to education, and characteristics of the child and the child's family which determine behaviour with respect to investing in human resources development. In most of the current applications of the Bachue models the supply side (i.e. the education facilities and government policy) is treated as the main determinant of such rates. In most developing countries, this approach is probably acceptable as a first approximation. Existing household survey data were inadequate for the testing of more elaborate models which incorporate both supply and demand factors. With some differences between the models, education rates are

Table VIII Education

	Brazil	Kenya	Philippines	Yugoslavia
Dependent variables	Probability to belong to one of the four education levels, R/U	Enrolment, repetition and completion rates by age, sex, R/U	Conditional rate of success in primary and secondary determining three education levels, R/U	Enrolment rates in higher primary, two secondary, tertiary by sex, A/NA. Enrolment rates in lower primary, drop-out rates from all levels by sex, region, A/NA.
Explanatory Variables	LFPR, household income public expenditures for education, sex, age.	None	None	Enrolment in lower primary and drop-out rates exogenous and/or policy variables. For higher primary rates: young age dependency, NA father's education, A child LFPR, regional dummies. For secondary: labour supply, education level, employment growth, unemployment, child and female LFPR, % young women married, father's education, regional dummies. For tertiary: % general secondary graduates, % tertiary level labour supply, father's education, secondary education, unemployment
Comments	Logit estimation. Aggregated population census data.	Changes in rates: policy variables. Source of initial rates: Ministry of Education data.	Changes in rates: policy variable (constant growth of the logit). Consolidation of education levels into two levels for labour market. Due to definition of dependent, completion and failure are mixed. No distinction in demographic accounting between enrolled and not in school but computed separately. Computation of investment and recurrent cost of education using student/teachers ratio.	Linear specification. Population census & socio-economic aggregated data for 79 demographic regions. Adjustment of intercepts and dummies to region, A/NA, sex specific, enrolment rates. Expenditure for education endogenously explained in separate sub-system.

thus considered as policy variables or determined by over-all government expenditure patterns. The effective demand for above primary education is explicitly represented only in the application to Yugoslavia, where enrolment rates are treated as functions of household and labour market characteristics, as well as of exogenous policy instruments. In Brazil, the school system itself is not explicitly modelled. Instead, probability functions for educational level at different ages are specified as a function of both supply and demand variables.

X. Conclusions

Drawing general conclusions on the treatment of demographic variables in the Bachue models with a view to simplifying the construction of similar models, under other circumstances, is a difficult exercise. Here and there in the pages above, comments have been made on the validity of one approach or another; for instance, the omission of structural features when estimating behavioural equations, especially using individual data, has been mentioned; comments were also made about the time period used in the simulation. But a general conclusion appears impossible. The main constraint, in our opinion, is that a systemic model, i.e., the representation of the structure of a system, is exclusively defined spatially and temporarily, hindering the transfer of parts of one demographic system to another and even the comparison between them. For instance, it would be foolish to compare the structure of the demographic system of Bachue-Yugoslavia with that of Bachue-Kenya with a view to determining the better one. Indeed, the validity of the representation of a system mainly depends on its ability to simulate the dynamics of measureable phenomena, such as the population growth rate or the quantity and quality of the labour force, and not so much on the underlying theories.

Another factor which does not facilitate comparisons between models is that each country application has been developed under specific conditions determining particular features of the model. Data availability is one of these conditions. Certain aspects of the demographic sub-system of Bachue-Brazil had to be simplified because of a lack of suitable data. The presumed interest of potential users, notably the interest and involvement of policy makers in the outcomes of the model, is another condition shaping each model. If Bachue-Philippines had been built in the Philippines, it is likely that family planning programmes and fertility functions would have been treated quite differently.

Given these problems of comparability, the conclusions will be limited to some general comments on endogeneity, on the demographic accounting and on certain issues raised by the estimation of behavioural functions and their introduction in the model.

(i) Endogeneity

While the endogenous nature of certain demographic elements of a demographic model is clear, the construction of the Bachue models has shown that there are no precise rules valid for all cases, i.e. adequate to describe different socio-economic systems and to satisfy all possible users. As mentioned above, there is considerable variety in the way characteristics of the population

have been represented in the various applications. To some extent at least, this variety reflects the mechanisms of the system described, and the validity of the representation of the structure should be considered as the main criterion to decide on the endogeneity of an element.

Some examples can illustrate this point. It has been seen that in Bachue-Brazil, marital status has not been introduced in the present version of the model. Actually at least three types of marital status would have to be considered: single, legally married and consensual union. The other sub-systems of the model do not take into account the differences between these three marital statuses, so that this distinction would have no consequences and could therefore be redundant. But a more detailed analysis of the generation of poverty, and of the behaviour of certain classes of migrants in the labour market might need to remedy this omission. Previous socio-economic studies have shown the precarious situation of women living in consensual union, more likely to be forced to work than those in regular marriage, and when working, often paid less than the minimum wage. There is therefore a case for disaggregating labour market and income distribution systems by marital status. This is a case where the level of disaggregation of one sub-system of the model has direct implications for the level of disaggregation of other sub-systems. Does this suggest that marital status should be an endogenous element or is it sufficient to consider it as a parameter? The answer is not straightforward; it depends partly on the structure of the system, partly on policy objectives in model design and partly on the availability of data. The mechanisms of the system can be such that none of the other elements of the whole system influence the dependent variable in question. To take a different example, in explaining mortality in the Kenyan model, access to piped water and the prevalence of malaria are both significant determinants of mortality, but neither lend themselves to endogenisation using variables available in the model. The approach adopted, taking policy objectives into account, was to assume that both are under government control. In the Kenyan case, these exogenous elements have been consolidated into one single trend; another more detailed approach would have been to keep each variable separate, either changing it from time to time to simulate policies, or letting it change systematically over time.

If an element is known to be endogenous but data are not available to measure quantitatively its dependence on other elements of the system, the question for model builders is whether to retain the element as a parameter or to use simulation techniques to represent the assumed relationship. Although simulation has a poor image in many circles, the authors of the present paper and probably most of those who have worked on Bachue models would favour such an approach. It is no doubt risky to work with best guess "estimated" relations; but assuming unchanged coefficients is even less reliable. In the marital status example above, an acceleration of migratory flows might increase the number of women living in consensual union, and thereby have a considerable secondary impact on employment and poverty. Keeping a constant ratio between the types of marital status would hide this phenomenon.

(ii) Accounting

The Bachue models have often been criticised for the size and complexity of their demographic systems, either in comparison with that of the economic system, or in comparison with the magnitude of changes occurring in the short and medium term. For medium term models, it is often argued that a full demographic accounting and behavioural system is not necessary and could be replaced by simple extrapolation of the main elements. This point is valid to the extent that the model is essentially aimed at broad relationships between the economic and the demographic systems, but there are several practical reasons in favour of a complete system.

The first one is that, in contrast with economic models, a complete demographic accounting is probably easier to develop than an abridged version. If the model is simplified too much certain elements, especially those which can have short term effects and are therefore of greater relevance to policy makers, tend not to respond to changes in the system. For instance, this might concern the proper accounting of new entrants in the education system, the sex ratio of entrants into the labour force or the tracking of spatially disaggregated populations. In Bachue-Philippines, the computation of the school population, which is a simplified ex-post addition, is adequate for the purposes of the model but would probably be considered insufficiently detailed by education planners.

Another reason for avoiding excessive simplification, is that the outcomes of a detailed accounting, while perhaps not relevant to the medium term dynamics, may be much more relevant for partial planning. It is of interest to education or health planners to know, rather accurately, the eligible population according to certain characteristics.

A third reason is that a complete accounting can be adapted rapidly to various needs, by dropping, ex-post, redundant information. If additional information has to be generated by extending a simplified system, a long and tedious programming task is often implied. Taking the example of Bachue-Philippines, the lowest educational level of the population is likely to become redundant once education is generalised to all classes of the population, but it is quite easy to reaggregate when needed.

Meanwhile, there are obviously valid arguments (cost, ease of interpretation, etc.) in favour of small systems but the experience with model construction tends to show that the redundancies can only be eliminated after and not before the sensitivity of the model has been fully tested.

(iii) Estimation and Use of Behavioural Equations

The estimation of behavioural relations raises two main questions: the source of data and the type of function used in the programme. The Bachue-models have used a mixture of international and national cross-section data sources to estimate the behavioural functions of the demographic sub-system. In so far as national cross-section data sources are used, either individual or aggregated data can be used. Time series or a combination of cross-section and time series can be used, and in principle are highly desirable in order to pick

up dynamic behaviour. However, adequate time series data were not available for any of the applications.

The use of international cross-section has almost always resulted from the lack of national data sources. The main exception is the fertility function of Bachue-Philippines where international cross-section data were preferred in view of the inadequate dynamics of an equation estimated on national data. International crosssection data offer some advantages, but also suffer from many drawbacks. Firstly, the range of explanatory variables is very limited, especially in comparison with the number of elements available in the model itself. A complete "explanation" of any demographic phenomenon is out of the question. Secondly, international cross-section data give an average measure of phenomena, whereas at the national level, regional and inter-group differences may be crucial for an adequate analysis.

Thirdly, international cross-section data, because of their very nature, are highly multicollinear. This makes it difficult to separate out the effects of different independent variables, and also the coefficients of explanatory variables may actually be reflecting the influence of other collinear variables not in the model. For long term oriented models looking at broad trends, the explanatory variables are all likely to move in the same direction so that the behavioural function as a whole can provide satisfactory simulation of the phenomenon. In contrast, if the model is policy oriented, designed to look at the effect of shocks on the structure, variables are no longer moving in parallel. In this case, each coefficient should represent the sole effect of the variable concerned so as not to bias the policy simulation results.

Aggregated national data can present the same drawbacks as international cross-section data, though the bias is smaller and depends on the criteria of aggregation: for instance in structuring data by income groups, one often introduces a systematic bias (Theil, 1971). Micro data (i.e. data at the level of the decision unit, whether individual or household), do not present these drawbacks but because of the magnitude of the error term, the level of statistical significance of the equation estimated can be very low, which casts doubts on its structural validity. When a set of equations is estimated on individual data, for instance labour force participation by age groups, the coefficients of a variable can differ widely from one equation to the next, making the age pattern difficult to explain. For purpose of sensitivity analysis of model behaviour, and also to make model structure more coherent, it would be desirable to have a smooth pattern of coefficients, e.g. by deriving from the original coefficients a consistent pattern over age-groups. It is obvious that large fluctuations of the coefficients result from the random character of individual data which no model is able to explain, and which is of little relevance for a model describing the behaviour of groups, generally in a deterministic way.

Related to this issue, there is the problem raised by the estimation of behavioural functions with a view to using them in a much wider context. Should one estimate the best possible function and use it as such in the simulation or is it better to lose some capacity to explain the variance in order to control

the simplicity of the explanation? This problem is illustrated by the estimation of equations in Bachue-Yugoslavia where the basic disaggregation is by republic and mode of production (private and social). In this case, there is the possibility (a) to fit one unique specification of the function to the whole sample and to compute the value of the dependent variable in each sub-group, from the values of the explanatory variables in that sub-group; (b) to introduce in the specification of the general model, dummy variables which would account for the differences between the sub-groups (this is different from the previous approach as differences between sub-groups are predetermined to the model), and (c) to fit the best specification to each case, perhaps reaching rather large differences from one specification to another. The first approach (unique general model) can be dangerous as the necessary calibration of the equation on the initial data can hide very large specification error. The second approach at least draws attention to the differences though it does not explain them. Indeed, if dummy variables on the intercept and on the slope of the explanatory variables are significant, they actually compensate for specification errors, such as the omission of institutional constraints or other macro effects. The third approach is obviously preferable for understanding a demographic phenomenon, but does not necessarily provide the best behavioural equations for a demo-economic model; often such equations are too complex, containing numerous exogenous variables for which a satisfactory evolution over time has to be decided upon (cf. the example above on the determinants of mortality in Bachue-Kenya).

There are numerous other issues raised by the estimation of behavioural equations for a demo-economic model and by the construction of such a model, such as the omission of dynamic factors using cross-section data, the difficulty of combining micro and macro elements in a behavioural function, or the dangers in extrapolating the behaviour of individuals or households to that of a group, or that of a whole population to sub-populations. There is no general solution to each of these problems and the best ad hoc solution for any given situation has to be looked for. In consequence, the construction of demo-economic models still faces significant conceptual and technical difficulties. Some of these difficulties derive from data inadequacies. However, the lack of data is probably no longer the major constraint on the construction of such models (although data are sometimes deficient in quality and in comprehensiveness, and often biased in the way they have been collected to test one a priori hypothesis). Nor is the extent of economic and demographic theory a major limitation - indeed as far as theory is concerned the problem is the "trop plein" rather than the "vide". The major problem in building demo-economic models lies more in the formalisation (including the quantification) of all sorts of partial theories and empirical knowledge into a coherent and global frame, rather sophisticated in some ways, but also highly imperfect; and after this formalisation, to convert this conceptual structure into a tool which can be effectively utilised for understanding a social system, and for evaluating attempts to modify that system through policy interventions.

APPENDIX

Towards a Household Accounting System

i) Introduction

In this appendix we discuss the design of a sub-model which is able to track households, broken down by certain demographic and socio-economic characteristics, in a manner similar to the tracking of population cohorts. Such a system is required because several of the behavioural relationships and data bases of the Bachue family of models are defined at the household level. For purposes of this section we shall neglect the thorny problem of conceptualisation of a household, and assume that groups of individuals taking certain decisions together and sharing certain characteristics can be identified.

There are several different ways in which the problem can be approached. One alternative is to add to the basic population accounting system a dimension measuring the nature of the household to which each individual belongs. Rather complex mapping procedures would be required to convert information stated in these terms to over-all information on households, and we see no easy way to deal with this problem. A second, but only slightly simpler approach would be to eliminate the population accounting system altogether and only track households. At any given point in time, the knowledge of the number of households and their composition would permit us to calculate the number of individuals of particular types. Unfortunately, because of the complex and varied nature of households, a complete tracking is much more difficult than the tracking of individuals in a conventional demographic accounting system. The third approach, and the one which is adopted here, is the building of a simplified household accounting system on the basis of population accounting and socioeconomic information. In this procedure, households are not tracked from period to period, but "reconstituted" within each period. For instance, changes in the composition of employment are reflected in the distribution of households by socio-economic group, without it being possible to identify the specific groups which gain or lose, and therefore without the possibility of reproducing the "history" of specific groups.¹

Thus the approach proposed does not capture the generation and interaction of classes of households, but rather tracks the numbers of individuals and households, but in a predefined set of classes. Qualitative or quantitative relationships describing class interactions over time might be envisaged as a subsequent development of the system but is not treated here.

We discuss the proposed household accounting system under four headings: (a) the determination of the number of households, broken down by demographic criteria; (b) the socio-economic characteristics of household heads; (c) the socioeconomic

¹ To reproduce the history of groups, one approach would be to break down the population into as many categories as desired, and to track the movements of individuals from one sub-population to another due to the education of children, professional mobility, etc., in a way similar to migration between urban and rural areas. Such socio-economic mobility is theoretically easy to represent, but household formation in such a framework would still be "cross sectional" or static, because household structure would still have to be superimposed on a pattern of outcomes of individual behaviour.

characteristics of non-household heads; and (d) the constitution of households from this information system. An outline of the different components of this system and their relationship to other parts of an economic-demographic model are given in Figure 1.

ii) Determination of the Number of Households by Age,
Sex, Educational Level and Location of the Head

The determination of the number of households follows the basic disaggregation of the population. For each age/sex/education/location category, headship rates are calculated. These headship rates give the probability that an individual in that demographic category will be the head of a household. By definition, of course, the number of households equals the number of household heads. The headship rates themselves are made endogenous in terms of several different explanatory variables. Thus the probability of being a household head will depend on the age at marriage (itself endogenous as a function of other variables); on mortality, and sex differentials therein (e.g., adult male mortality leading to a larger proportion of female headed households); on migration, especially if it is sex specific, and on household structure (so that there will, for instance, be lower headship rates at younger ages in a society based on extended families). The shift from one family structure to another should itself be endogenous, and might be a function of changes in socio-economic variables such as the mode of production, the average education level of the population and other related factors. In addition to these demographic phenomena and their socio-economic determinants, one could envisage a direct impact on headship rates of economic variables such as the rate of unemployment and the production structure.

iii) Socio-Economic Characteristics of Household Heads
(Matrix HEAD)

The next step is to distribute households by certain socio-economic characteristics of the head. It is assumed that characteristics of other members of the family can be regarded as functionally related to those of the head. The net outcome of this process will be to form an additional dimension to the matrix discussed in the last section.

The socio-economic characteristics which need to be taken into account primarily concern the occupation and the production sector. Education, age and location are already accounted for. Although there would be some reason to attempt a disaggregation by income as well, the conceptual problems which arise are such that it seems wiser to regard income levels as a final result of the system rather than as one component of it.

Two special socio-economic categories of heads, the unemployed and the inactive, both quite important as far as income distribution and poverty are concerned, are treated separately from the rest of the matrix. Changes from period to period in the number of unemployed heads are normally associated with changes in total unemployment except that heads are more likely to obtain a job than non-heads, and less likely to lose it. Causes of changes in the number of inactive heads are less obvious, except for those due to retirement. For heads below

retirement age, inactivity can perhaps be linked to the socio-economic characteristics of the household itself, especially household income and the number of actives. If such a solution is to avoid problems of simultaneity it requires a recursive relationship - i.e. the current period inactive rates would be related to prior period income and non-head's activity rates.

Once the number of inactive and unemployed heads has been estimated, it is necessary to distribute active heads by socio-economic characteristics. At this point in the model the over-all distribution of the population by these characteristics is known, so the problem is one of defining the proportion of different sub-populations who are heads of households. In Bachue-Philippines, the equivalent relationship was estimated on the assumption that the relevant proportion of household heads is constant, relative to the over-all incidence of heads in the population. This hypothesis could doubtless be improved upon by making the distribution a function of many different factors. For instance it might be assumed that heads tend to occupy the best jobs when such jobs are created, and to stay longer in declining secondary activities. Other such relationships can be identified, but clearly more empirical research is required. The over-all distribution of heads by socio-economic category does not need to be broken down at this initial stage by the demographic characteristics described above, although for certain demographic disaggregations (e.g., male/female, rural/urban and perhaps across age groups), the differences between groups in the determinants of socio-economic distribution patterns would probably be large enough to warrant disaggregation eventually.

Once the number of heads by socio-economic characteristics is known, and knowing the distribution of heads by the demographic characteristics described above, the complete matrix of coefficients (for which initial data are assumed to be available) can be up-dated by using one of several techniques. The "RAS" procedure is the simplest and most commonly used. At this stage the matrix HEAD would have been estimated, with dimensions of age, sex, education, location and various socio-economic characteristics.

An alternative procedure would be to explain changes in all the elements of the matrix separately. However in Bachue-Philippines the matrix would have had some 10,000 cells, which suggests that this would not be a practical proposition.

iv) Socio-Economic Distribution of the Population of Non-Heads

Simple subtraction of heads from the total population gives the distribution of non-heads by the same categories as the heads - by demographic criteria on the one hand, and by socio-economic criteria on the other. One important additional disaggregation in the inactive category is to separate out children whose primary activity is schooling, since this is a useful variable to be able to output.

v) Constitution of Households

At this stage we have available the socio-economic and demographic characteristics of household heads and non-heads given in matrix form in each subpopulation. These two matrices are now to be combined in various ways to compute the number of

and socio-economic distribution of non-household heads according to the characteristics of the household head. The main variables required from this computation are mean household income; variance of household income; activity status of household members; family size and age/sex composition; and the education of children.

In order to design a system which provides this information, a number of assumptions are required. The simplest possible assumption would be that the head:non-head ratios implicit in the initial values for this system (assumed known) remain constant over time. This is essentially the assumption of Bachue-Philippines and Kenya. However this approach fails to allow for important differentials in behaviour. For instance fertility decline, and consequently household structure and income distribution, is likely to be larger in highly educated households whose members work in modern sectors, than in subsistence agriculture.

We therefore require behavioural functions which allocate non-heads to households as functions of the characteristics of the heads and of the non-heads, while maintaining accounting consistency in the relationships as a whole. An example of such a function would be a relation between the number of dependents, or the number of actives per household, and various socio-economic and demographic phenomena. This can be set up as follows:

Let $Y_{ij}(t)$ be the average number of persons (or of economically active persons) in households with characteristics i, j in period t .

Let $\bar{Y}(t)$ be the mean number of persons (or actives) per household in period t .

Let $X_{ij}(t-1)$ be household income of households in category i, j in period $t-1$.

$F_{ij}(t-1)$ fertility in i, j in $t-1$

$M_{ij}(t-1)$ mortality in i, j , in $t-1$

$N_{ij}(t-1)$ net migration of non-heads in i, j in $t-1$

Then a plausible relationship to explain Y_{ij} would be:-

$$Y_{ij}(t)/\bar{Y}(t) = f(Y_{ij}(t-1)/\bar{Y}(t-1), X_{ij}(t-1), F_{ij}(t-1), M_{ij}(t-1), N_{ij}(t-1))$$

Education levels might also enter this relationship, and some of the independent variables might be expressed relative to the population mean (e.g. $X_{ij}(t-1)/\bar{X}(t-1)$ instead of $X_{ij}(t-1)$).

Note that this function is intended as an approximate replacement for determination of Y_{ij} through complete tracking of F_{ij} , M_{ij} etc. The dependent variable here can be regarded as measuring trends away from the initial values for each socio-economic-demographic category of household heads, as a function of socio-economic-demographic changes. The independent variables of this function would in general be lagged so as to facilitate model solution. Among the implications of this approach it should be noted that the independent variables of the

function should, as far as possible, be disaggregated by the economic-demographic categories of matrix HEAD. A particular problem arises in the case of migration, since migration can involve changes in location for either individuals or for household as a whole. It is suggested that separate migration functions for heads and non-heads would need to be specified. Another point worth noting is that consistency between the results of this procedure, and the number of non-heads calculated in Section (iv), is required. This is easily handled through an equi-proportional scaling.

The net outcome of this process then is that a mean household size (and if necessary, age/sex composition) and a mean number of actives (also broken down by age and sex as far as is necessary) will be identified for each cell of matrix HEAD. The next step in the process of computation of household income is the use of the matrix distributing non-heads by socio-economic category according to the head's category. At this stage all the elements necessary to update such a distribution matrix are available: the socio-economic distribution of heads and non-heads, and the number of actives by category of the head. It is proposed to update this matrix from period to period through RAS-type adjustments, as is the case in Bachue-Philippines. This provides all necessary information to compute household income as well as income per capita within a household. Various transfers can also be introduced at this stage, as well as their disaggregation by socio-economic-demographic characteristics. It is also possible to introduce relations to allow for income variance within each of the socio-economic categories identified, using procedures analogous to those for the mean.

In computing the average number of persons per socio-economic category, children born during the previous period will already be accounted for. However the fertility function will itself depend on, and as far as possible be disaggregated by the socio-economic breakdown discussed here. Most socio-economic variables explaining fertility are directly available or easily generated from information about socio-economic-demographic disaggregation. For instance, if the fertility function involves the education of the mother, and the latter is not the household head, a simple deterministic relationship might be established between her education and that of the household head. However it should be noted that while fertility can be disaggregated in this way by socio-economic group, the procedure proposed does not permit the tracking from period to period of the number of individuals in given socio-economic categories, and their evolution over time. This would require a comprehensive accounting system involving impossibly large matrices. Even the information required by the system proposed here presents formidable data handling problems. Some of these can doubtless be reduced by replacing say, a complete age distribution accounting by a three or four parameter function such as Coale's marriage and fertility functions. In this case the objective would not be to explain the allocation of population to different age groups directly but rather to explain the parameters of the function, and to rebuild the age distribution within each period.

With respect to the treatment of education, we can consider two cases: (i) demand variables are used in computing education-related rates (enrolment, drop

out, etc.). In this case, the over-all enrolment rate can be computed from the rates within each sub-population which in turn depend on the characteristics of that sub-population. Dynamics of enrolment and drop out within each socio-economic demographic group, however, would not be tracked. The over-all rates would be applied to the education system to up-date the educational level of the population, without differential rates in different socio-economic groups being tracked. It might however be desired to include in the model estimates of school enrolment by socio-economic group (i.e., population in school as opposed to rates of school entry and drop out), since information of this type is important for labour supply, fertility and other functions. To meet this need a simplified system could be worked out. For instance, an approximate relationship between current enrolment and drop out rates and the pattern of participation in schooling at different ages can be worked out and applied to give an approximation for each socio-economic group. (ii) Schooling rates are not related to household characteristics but are exogenous and reflect only the supply side (as in Bachue-Philippines). In this case the link between school performance and household characteristics requires additional behavioural relationships to be specified, either within or outside the model.

A final comment is worth making on the measurement of socio-economic mobility. As noted above, mobility is not explicitly and dynamically incorporated in the system proposed here. Nevertheless, for some purposes - analyses of certain types of policy for instance - it is desirable to have at least a first approximation to the dynamics. A simple approach, although a purely statistical one, is as follows: the distribution of household heads and members in period (T-x), and the same distribution in period T, would be regarded as the marginals of a matrix for which the initial estimate is unity on the diagonal - i.e., immobility. Estimating the coefficients of this matrix, using once again the RAS technique, would give an estimate of net mobility between categories. The problem could be simplified (and made more realistic) if additional information were utilised to specify certain types of mobility which are impossible or absent. More sophisticated statistical methods are available to estimate mobility, such as the estimation of a transition probability matrix using Markov chains. However given the approximations involved the simplest procedure seems to be the most appropriate one.

Figure I: Household Accounting

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