Relations between Population and
Economic and Social Development

On the Use of Models in Prospective
Population Studies

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Recent Developments in Demographic Analysis.

In recent times, mathematical methods have come to play a certain role in a deeper analysis of demographic phenomena. At the same time, the development of computers and data techinique has made it possible, on the one hand, to handle large population-statistical materials and, on the other, to deepen the analysis of these materials. A further development is that by a combination of mathematical and data technique arrangements it has been found possible to build models of population dynamics which give a clearer view of the connections between different demographic phenomena.

The relations between the demographic factors and various non-demographic conditions and factors of an economic, social and cultural nature, valuation aspects, institutional conditions, etc., have naturally appeared in the background of demographic studies. However, the possibility, and the methods, have been lacking of expressing in a more tangible — and preferably quantifiable — form the influence of the non-demographic factors on the demographic ones, and similarly, in the opposite direction, the effect of the demographic factors on economic, social and cultural etc. conditions and changes.

Up to the present, these questions have been approached in the first place by studying how, for instance, mortality, fertility, etc., vary between different groups of populations with economic, social, cultural, ethnic, religious, geographical etc. separation. In this way, preliminary information has been obtained about these relations, but it is clearly a long step from noting correlations to carrying out an analysis of causes.

This has involved a serious handicap as regards the possibility of making meaningful population projections. Efforts have had to be restricted to simple extrapolations of what has been observed so far. During a period when population changes have become very powerful and, in part, of another nature than previously, it is evident that this has impaired to a high degree the value of the projections we have felt able to make. The new developments in demographic methodology, however, open up prospects of getting considerably farther here.

What has been and still is troublesome for the making of prognoses is that there has been no means of measuring and analysing migration in a realistic way, geographically as well as from the socio-economic and cultural aspects. Here also, we have had to content ourselves with a possible extrapolation of observed conditions during the most recent past.

In order to obtain a realistic method of explaining the role of migration in a population model, we can assume that the labour force is the principal factor in the course of events, and that other migration can be adapted secondarily as a function of the structure of the population and the migration of labour force.

The labour force migration can be said to be the expression of an imbalance in the economy's labour force situation. A surplus in one area then finds its way or is transferred to areas in which there is a lack of labour force.

The mechanism which provokes migration is of course dependent upon a number of circumstances: the economy's structure and geographical distribution, the society's form of government, the psychological and socioeconomic conditions at micro-level, and so on.

Regardless of the way in which this provocation of migration works, it is evident that it is strongly dependent on the economy's functioning, balance and changes. To get a realistic view of this interplay one must imagine a model which includes labour force, natural resources, level of production technique, socio-economic factors, institutional conditions, etc.. The demands made on such a model will be great, since the labour force migration appears as a difference between the much larger quantities, supply and demand of labour force. The problems are made more difficult if a qualitative division of labour force is introduced with respect to *age, health conditions,* and *level of education.*

In order to attain a general dynamic model of the »social mechanism», it is necessary to proceed step by step. As a first step, a model without migration is worked on, where the growth of population is built into a closed system which, at the same time, allows a corresponding growth of the economy, social factors and other conditions. Only when it is considered that the mechanism of such a model has been fairly well mastered are the means available to expand it by introducing migration as a new factor, which may have a relieving effect with an excess of labour force and act as a stimulant in case of a lack of labour force, through a new in-migration.

The Population Sector in a Universal Model

At the Demographic Research Institute in Göteborg a research project is just now in progress on the design of the population sector in prospective studies, and particularly in connection with models.

This project has its point of departure in the Rome Club's study »On the present and future predicament of mankind», presented in *The Limits to Growth* (D. Meadows et al., 1972).

The Club of Rome's study is based on a global simulation model — the »World Model» — which, tecnically speaking, is built up on a special technique of system analysis, presented in *World Dynamics* (J. Forrester, 1971).[1]

The discussion following the publication of *The Limits to Growth* has mainly been centred on the technique employed in the construction of the »World Model», and has thus been of a methodological nature. It has been shown that the technique of System Analysis is highly sensitive to even minor changes in the model structure.

It is therefore extremely important for the validity of the model

(a) that all relevant factors and subfactors should be included,
(b) that their interrelations should be correctly formulated, and
(c) that their quantitative values should be well estimated.

These considerations are especially important for the Population Sector. Unfortunately, the various demographic factors have not, so far, been with sufficient accuracy in this respect.

The research work at the Demographic Institute in Göteborg is directed towards improving the construction of the Population Sector of the »World Model» to an extent such that the demographic processes can be regarded as described with the necessary accuracy and as well in balance with other sectors.

This paper will take up some of the most essential criticisms of the »World Model», and will present some ideas for its improvement developed at the Demographic Institute.

At one of the first meetings of the Club of Rome, those present came in contact with the methods worked out in the field of system analysis by Professor Jay Forrester at the Massachusetts Institute of Technology (MIT). One felt persuaded that these methods were suitable for bringing increased light on the problems of »the present and future predicament of mankind».

A group was built up around Forrester in order to take up the essential factors in a global System Analysis. The System Analysis is presented graphically by means of a set of boxes and circles linked by arrows which indicate various types of connection. Such a picture is naturally interesting,

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1 This special technique is designated System Analysis in the following pages.

fascinating even, for those who are used to employing graphic methods to illustrate connections and relations. However, even the first presentations raised doubts whether this method was practicable.

The method involves a high degree of aggregation of the various phenomena. This means that the relations between these different aggregates became a distorted reduction to a few dimensions of the very large quantity of relations that would be found in a differentiated model with all essential subfactors and variables.

Where quantification is concerned, difficulties arise however one proceeds. A highly differentiated model with many factors requires an enormous amount of relations and equations, the majority of which cannot be quantified, and can often be barely quessed at. A serious point is, further, that it is easy to be guilty of so-called false correlations when projecting down to two or three variables the relations that exist in n-dimensional space. It may be seen, too, from the reports that appeared later, that these particular types of error were actually committed. In so doing, one can even at times get the wrong sign for the relations that partly support the whole model.

The first World Model worked out by Forrester and the group around him has been followed by several others with Dennis Meadows as project leader. The number of factors included has increased, as has the number of relations and feedbacks. The various sectors into which it should be possible schematically to divide the model are, of course, unequally developed and differentiated.

As mentioned earlier, System Analysis is extremely sensitive to changes. This means that the absence of certain essential factors or relations and feedbacks, or the presence of deficiencies and errors in quantification of the relations referred to, has a very powerful effect on the whole system.

An example of this may be seen in a study by the Shell group in Holland (Dr. H. de Vries). In the MIT models, no expressions are included for valuations and price mechanisms. One thereby arrives at the absurd situation that non-renewable resources, for instance some metal or other, could be completely exhausted. In actual fact, this would naturally never occur. Long before this situation is reached, efforts are made, under the influence of price changes and so on, either to find substitute material or to try alternative techniques and methods, or to make use of recycling for recovery of materials, or finally to damp down the consumption of goods quite simply by an increase in thrift.

By setting in a couple of feedbacks which can express this mechanism in a simple way, it would be possible, while maintaining the System Analysis method, to show that these additions had radically changed the whole picture of the dynamic course of events in the future. There is therefore reason for asserting the following: Even if the model is as realistic as

possible on individual points and is considered acceptable, there will none the less be found considerable risks of error and deviation.

In the first presentations by Forrester and Meadows, population was given only rudimentary treatment. There was a block, called »population», with an entrance, births, and an exit, deaths. In practice this meant that the only measurements used were the crude birth and death rates per 1000 inhabitants. During »normal» conditions and slowly occurring changes these measures can, of course, be employed, but in the more divergent or extreme circumstances which Systems Analysis had wanted to make clear the measures in question are decidedly unsatisfactory and give misleading results.

It should further be observed that the allocation of starting values to these measures is inconsistent. The crude birth and death rates were set at 4.0 % and 2.8 % respectively. These values correspond to the observed average yearly values for the world during the period 1900—1970 — with a population growth of 1.2 %. They were then kept constant during the whole projection which started in 1900, but were modified to represent the influence of the four factors: pollution, crowding, food supply and material standard of living.

The model is so constructed, however, that if the factors in the model indicated above assume values corresponding to the observed conditions in the year 1970, the birth and death rates are not modified. If one then considers on the one side the outcome of the model for 1970 in particular, which, on condition that the model has correctly determined the values of pollution, crowding, food supply and material standard of living, has an average population growth of 1.2 %, and on the other side the observed population growth for 1970, which was 2 %, this means that the model has a serious skewness at the start.

Later versions of the »World Model», however, have undergone changes at a number of points, and the above critical remarks have lost their relevancy in accordance with the changes.

In view of a further development of the model, the following conditions have been adopted as requirements for what would seem to be an acceptable population model as part of a universal dynamic model.

(1) The population should be distributed by sex and 5-year age groups. Hence, the development over time will be in steps of 5-year periods.

(2) Mortality is given, in a first approach, by age-specific mortality rates, $_5m_x$. In a second version morbidity is introduced, from which mortality is derived as being the lethal part of morbidity. Specification by sex is then also included.

(3) In the first approach, fertility is given by age-specific fertility rates, $_5f_x$. In the second version, fertility is expressed as the ultimate effect of age-specific nuptiality rates, $_5n_x$, age-specific natural fertility rates, $_5f_x$, and age-specific birth control rates, $_5c_x$.

(4) The vital rates in (2) and (3) are influenced by a number of modifying »factors». This is assumed to be expressible through »modifying relations».

(5) The sex-age-specific rates of morbidity (acute, chronic, lethal) make it possible to reduce the total population by sex and age to a sex-age distribution of the potential labour force.

(6) The potential labour force, obtained through (1) and (5), is supplemented by the introduction of education as a new factor. This is done primarily through a set of assumptions about the number of school-years attended in different age-period groups.

(7) A division of the world into regions that are homogeneous from demographic aspects.

(8) Sex-age differentiated migration flows between the regions primarily depending on imbalances in the labour force situation.

(9) A further factor to be considered is the proportion of women belonging to the active labour force.

(10) Finally, the consumption of goods and services may be considered as expressible in age-specific rates and numbers.

In order to be able to express the influence of non-demographic factors on demographic factors in a realistic, consistent and uncontradictory way, it is necessary to have concentrated measures of the latter. The technique employed is based on the assumption that these variables can be

Relations between influencing non-demographic factors and population
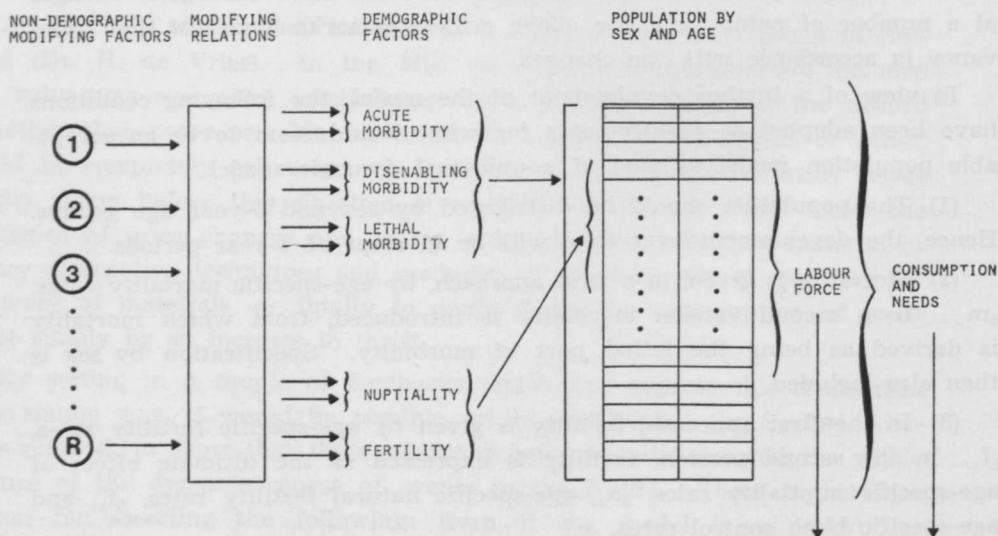
described through very few parameters or indicators. However, the technical details are excluded in this report, but they can be studied in a paper, H. Hyrenius: »*The Population Sector in a Global Dynamic Model*», presented at the IUSSP Conference in Liège 1973.

A graphical illustration of the total procedure for the population sector is shown on the adjacent page.

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