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ABSTRACT

A computer-assisted instructional (CAI) program at the University of Illinois is used to teach the dynamics of population growth. Socio-economic models are also developed to show the consequences of population growth upon variables such as income, productivity, and the demand for food. A one-sex population projection model allows students to project size age distribution, and other demographic characteristics under a variety of assumptions and parameters. A one-sector growth model illustrates the impact of population growth upon economic development, and other supplemental models are available if desired. Descriptive surveys show the program to be successful. It has enormous variety and generates much data with relatively little input. Students achieve awareness of population growth factors without having to undergo extensive mathematical training, and segments of the program have been utilized by instructors in several other disciplines. The program is primarily tied to the PLATO CAI system but a simplified version is ready for use with other hardware, such as the WANG 700 Programing Calculator and the Hewlett-Packard 9100 B. As CAI becomes available on other campuses, the program will be made accessible to a greater audience. (PB)

DYNAMICS OF POPULATION AND ECONOMIC GROWTH:

A COMPUTER-BASED INSTRUCTION PROGRAM

by

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Dynamics of Population and Economic Growth:

A Computer-based Instructional Program

CONTENTS

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by

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I. Introduction

It seems very essential in an undergraduate curriculum, particularly one in the area of social sciences, that a student understand the vastly different consequences of a two-child family and a three-child family on the socio-economic life and the quality of environment in the future. An understanding of basic mechanisms of population growth is necessary for students of demography. It will also benefit students in economics, geography, political science and sociology. Nevertheless, one cannot expect all undergraduates to go through the detailed technicalities of population projections.

In such cases, a particularly powerful tool in teaching population growth and its relation with economic and other social problems is a simulation of the population growth and the making of a projection of the population base of a economy or a society into the future. Such a simulation is also very useful for students specializing in demography to develop a feeling of the sensitivity of population growth to various

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demographic parameters. At the University of Illinois, we developed a computer-based instruction program for the dynamics of population growth. Based on this model, a number of socio-economic models are also developed to show the consequences of different population growth on the future labor force, incomes and productivity in a nation's economy, demand for food and energy, demand for social services, etc.

Our program of Population Dynamics and Economic Growth utilizes a computer-assisted instruction system called PLATO, developed by the University of Illinois.* PLATO consists of a central computer and a number of student terminals. The communication between students and PLATO is conversational. All instructions to use our program appear on a plasma display panel at a student console. A student can give instructions to the computer by typing them in at the terminal. The response time for a student request is on the order of seconds. Thus, an advantage of such computer-assisted instruction is that the students no longer need to be satisfied with a prescribed sample projection of population or economic growth shown in a textbook. In a fairly short period of time, one can study the dynamic path of growth of a population under many different demographic or economic assumptions.

II. Population Projection Models

The pivotal model in the program is a one-sex population projection model. It is supplemented by some auxiliary demographic models. The population base generated by the one-sex model is used by a number of socio-economic models.

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*See Daniel Alpert and Donald L. Bitzer, "Advances in Computer-based Education," Science, Vol. 167 (20 March, 1970) for a description of PLATO.

A. One-sex population model.

This model is used primarily for a projection of size and age distribution and other characteristics of a population under various assumptions. The starting population consists of an equal number of males and females in each five-year cohort. Cohort 1 includes ages 0 through 4; cohort 2, ages 5 through 9, etc. Cohort 17 includes all persons over 80 years of age. The starting population is moved forward in time by a recursive set of functions in five-year steps. The set of functions projecting the population into the future is determined by a set of specifications of total population, the age distribution of that population, the age-specific fertility rates, and the age-specific survival probabilities.

Currently, the system contains complete data for 32 different countries. In case of default in the specification of parameter values, currently valid data for each country is used in the projection. Projections with the specification of different parameter values under various demographic assumptions are also possible. This type of exercise together with some post analyses of such projections make the core of this lesson. In most cases, the implications are obvious, since graphing of projections of different populations or the same population under different assumptions can be performed within a single display panel.

For beginning students, age specific fertility rates (ASFR) seemed too complex and cumbersome. A student can choose to specify total fertility rate (TFR) instead. Then the TFR is transformed to ASFR according to the proportion of currently prevailing ASFR of the population.

Under a specification of the life expectancy or infant mortality rate, the age-specific survival probabilities are obtained from a standard life table* suitable for the population composition under study.

The projection of population is made by first computing the number of live births during a five-year period using age-specific fertility rates and survival probabilities (or mortality rates).** Then the total population and age distribution thereof is computed with age-specific survival probabilities. For cohort 1, an infant mortality rate of the student's choice can be used.

In the process of such a projection, changes in parameter values can be made either instantaneously at the beginning of the projection period or gradually over a specified period of time, one at a time or several simultaneously. Since the projection is made most often to examine the effect of different demographic assumptions, e.g., different fertility rates, the period over which the parameter values are to be changed is usually the period during which the target value of a demographic variable is to be achieved. An example would be a specification of the total fertility rate to be reduced from current level of 4.5 live births per woman to 2.1 in 20 years. When such gradual changes are made, usually a linear interpolation is made for the relevant parameter.

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*The life tables used were from Coale, A. J., and P. Demeny, Regional Model Life Tables and Stable Populations, Princeton University Press, Princeton, N. J., 1966.

**Algorithms are not presented because of space limitations. They will be available for interested people at the conference.

With the approach we described above, a remarkably large amount of output in various formats can be obtained with modest inputs of data. A student can obtain projected trends or simulations of dynamic paths of various characteristics of a population in both graphical and numerical forms. Examples of the graphical portions of some output displays are given in the illustration pages at the end of the paper.

The outputs can be obtained for each five-year period for time spans of from 20 years up to 200 years. The time spans over which the projection is to be made are also under the control of the student. Examples of outputs are: total population; age distribution; rate of growth of population at each time period; numbers of fertile women (15-45 years), children (0-15 years), school age children (6-17 years), and aged people (65+ years); dependency ratio; total fertility rate; births and deaths per thousand; number of population in an age group of any specification; etc. All except age distribution can be plotted in either a linear or logarithmic graph over a time horizon. The age distributions of total population or any subgroups can be shown in bar graphs for any future time.

Variations of the graphing schemes are almost limitless. Particularly useful routines were: multiple plotting under several different sets of parameter specifications (see Frames 1 and 2 in the illustration page); multiple plotting of two different populations (countries) (Frame 3); multiple plotting of two different groups in a country (Frame 4); etc. Comparison of trend paths under such multiple plotting has been most instructive since most of such displays are self-explanatory. While studying a particular population, students are encouraged to take account of some prevailing demographic conditions in experimenting with the projection model. A population history model described below is one example of guidance in choosing parameter values.

B. Auxiliary demographic models.

The basic one-sex population model is supplemented by a number of other demographic models. Those having been developed include: (a) Two-sex population model for separate projections of males and females. It teaches the concept of sex ratio, e.g., role of female in population dynamics, in addition to making more accurate projections. Algorithms are basically the same as the one-sex model;(b) Migration model to show the effect of internal (rural to urban) migration and international migration (immigration) on the population size and urban-rural distribution in a nation (Frame 5); (c) Population history model to show the past growth patterns of the population. Students can observe the changes in basic population parameters in the past. (d) Life table (mortality table) model to show the basic concepts and methods of constructing and using such a table.

These supplementary models are primarily for students in the principles of demography. The life table model and population history model are particularly intended to partially replace traditional descriptive textbook material. The life table model includes complete steps to construct a life table. The population history model only needs some explanation of possible causes of parameter changes to make it complete. In these auxiliary models, except in the history model, various types of changes can be made for the parameters. As in the basic model, multiple graphing for comparison under different assumptions are also possible.

III. Economic Growth Model

For the purpose of illustrating the role of population growth in economic development, a simple neoclassical one-sector growth model is used. In low income countries, population is a particularly important issue in development strategy. Again, a projection over time seems most illuminating to show the effects of rapid or slow growth of population on an economy. Unlike most other growth models in which capital alone determines the growth of output, in the current model both investment and available labor force take explicit roles in the determination of output.

A Cobb-Douglas type production function is the core of the model.

$$Y_t = A_t K_t^{\alpha} N_t^{\beta}$$

where Y is the gross national product (GNP); K, the amount of capital stock; N, the size of labor force; A, the multiplicative factor. For Y, K, and N, non-linear paths of growth are assumed. The labor force (N) is generated from the basic population model. Accumulation of capital (K) is performed by a capital formation subroutine. Since the parameters in the models to generate N and K are under student's control, the growth of all inputs and the output is non-linear. Thus their respective rates of growth, n_t, k_t, and y_t, are functions of time. The rate of growth of the multiplicative factor, r, intended to represent technological progress, is autonomous.

Since the production function is not applicable when a reliable measure of the initial value of capital stock (K) is not available, actual projection of GNP uses the relation between various growth rates implied by a Cobb-Douglas function. That is, $y_t = r + \alpha k_t + \beta n_t$. Then the level of output and per capita income are computed using the rate of growth of output for each successive five years.

For the capital stock variable, a fairly simplified version is adopted. The rate of growth of capital stock at any time (k_t) is obtained from a rate of gross capital formation and depreciation rate at that time. The concept of gross capital formation was chosen instead of savings ratio, so that the model can accommodate a wider range of conomic conditions. The students are expected to be given an instruction on the meaning of gross capital formation suitable for different types of underlying economic conditions.

The size of labor force is determined by the population base of the economy generated by the basic population projection model together with the sex and age specific labor force participation rates (LFPR) of that economy. Students can observe the growth of labor force over the time axis under different parameter specifications of the population or LFPR's. The age composition of the labor force can also be obtained in bar graphs for any specified future time point (Frame 6).

A student can use the current data of an economy for the projection. He can also opt to make instantaneous changes or gradual changes over a period of time of all economic or demographic parameters, one at a time or several simultaneously. These include rate of capital formation, rate of technological progress, parameters of the Cobb-Douglas function, fertility rate, etc. Since several projections under different assumptions can be plotted within one frame, the effect of different parameter values can quite vividly be demonstrated. A more drastic example is the effect on per capita income of a high fertility rate and very low capital formation rate which are typical in less developed countries, compared to that of low fertility and high capital formation (Frame 7). One can observe the declining productivity in the former case. The effect of zero population growth (ZPG) in the United States can also be demonstrated.

IV. Other Socio-economic models

A number of other subjects related to population growth can also be studied with other parts of our program. Space limitation does not allow us a full description of this part. Basically, our socio-economic models use the population projection model in a way the economic growth model does. Then a projection into the future is made under various assumptions. These models include demand for food, natural resource and energy consumption (Frame 8), effect on environmental quality, demand for social services (e.g., hospital facilities, doctors, nurses, residential units, etc.), and educational costs. These various socio-economic models together with the economic growth model are intended to enhance the population awareness, and provide the implications of different rates of population growth on various subject areas.

V. Evaluation and Concluding Remarks

Our approach proved to be a very versatile program. Variations in the dynamic projections and type of output are endless. The whole program is divided into several blocks which are interrelated. In one such block, no particular sequence of study is intended and a student has a free hand to manipulate the model in whatever way he desires. However, in most blocks, a lesson of a self-guided tour type (with enough flexibility built in) is used. This is done by a coordination of a workbook, and instructions on the display panel. The completion of one workbook takes about two hours during which over 50 exercises are made and their implications are analyzed. So far, two workbooks, one in the basic population model and another in economic growth, have been used. Since it proved to be effective in partially substituting for a conventional textbook, additional workbooks are being developed.

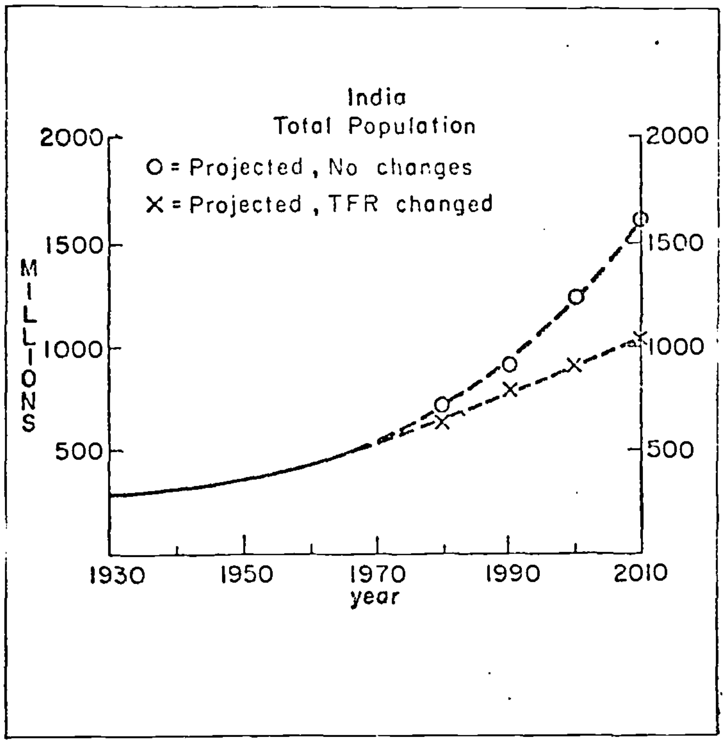
All or any combination of our models can be used with or without connection to a particular course. The program can be tailored for use over a period of two hours to an entire semester, depending on the purpose and interest of the instructor and students involved. This program was developed not only for use in our own courses, but to service instructors in various disciplines. The beauty of this program is that one need not go through mathematics of population growth or make an analytical approach to economic and social growth. Nevertheless, a student can learn enough about the essential dynamics of such growth models.

During the past eighteen months, instructors from thirteen different disciplines at the University of Illinois have used portions of our program as an integral part of their courses. Most programs were used along with classroom lecture of the subject material. Some parts, particularly the demographic portions, were used to substitute conventional instructor's lectures. Subsequently, a session was held to discuss the result and conclusions of each student. Since each student made his projections independently, a group discussion session was a stimulating period.

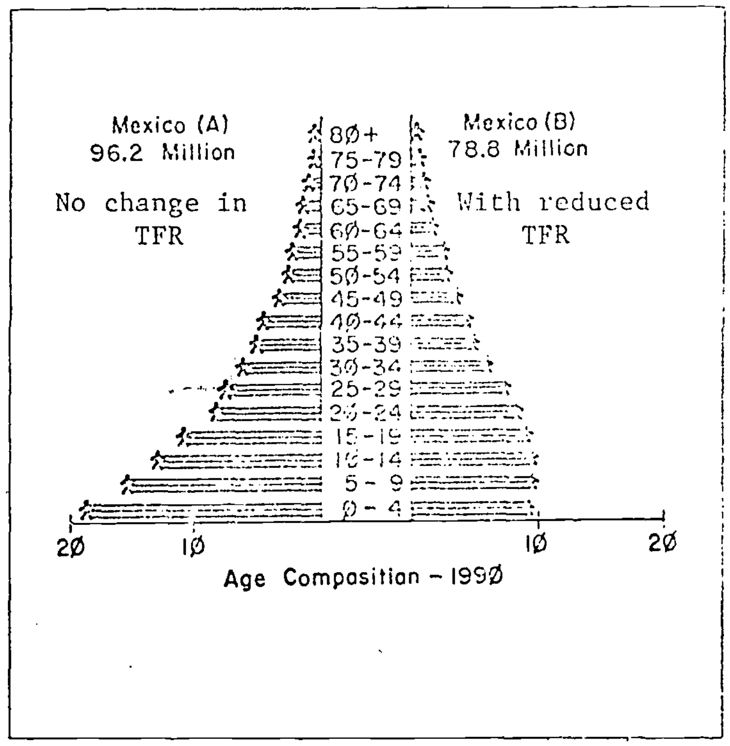
No systematic attempt has been made to produce a statistical evidence forthe effectivenss of our program in instruction. Descriptive surveys made on several occasions showed that the population awareness of the program users is substantially enhanced. Our main channel of feedback and evaluation is through our own audiences and instructors, who in turn communicate with their students. Repetitive requests of our programs from instructors are also an indication. Our conclusion is that the students do learn the dynamics of growth. However, "how much" is unknown. Some complaints from instructors included diversion of student attention by experimenting with unrealistic parameter values. To discourage such an exercise, most parameters now have upper and lower limits. Upon a specification of parameter values beyond this range, the computer will instruct to choose a different value.

Our program is primarily tied to PLATO. However, a similar but simplified version is also developed for use with a combination of a WANG 700 series Programming Calculator and a WANG typewriter-plotter. A slight revision will also make our program operational with other computers or a mini-computer (e.g., Hewlett-Packard 9100B). A student terminal of PLATO can be operated at a remote location. Currently, a few institutions in Illinois have such remote terminals. Very shortly, PLATO will be available in many campuses across the country. At that time, our program will be accessible to many students of social science who may benefit from an overall study of the dynamics of population and economic growth.

Illustrations



Frame 1



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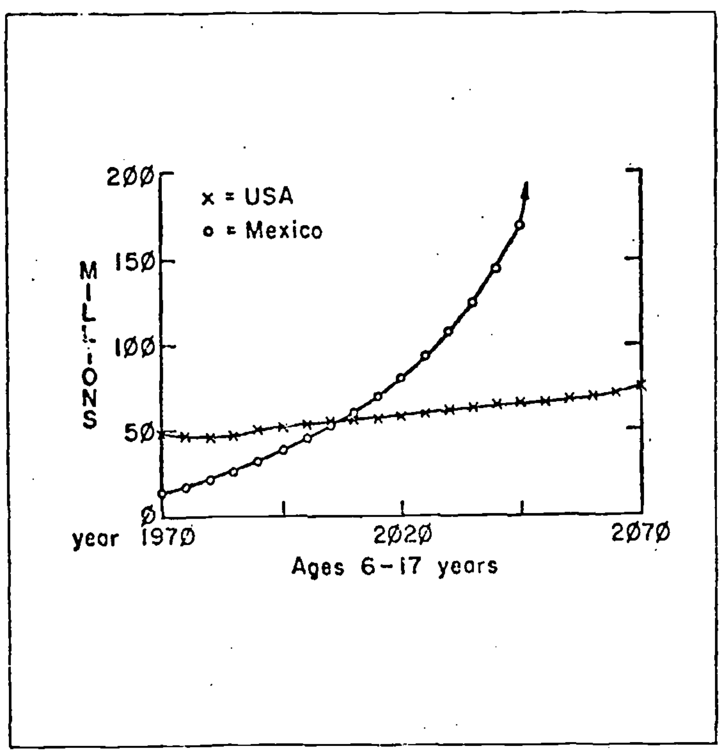

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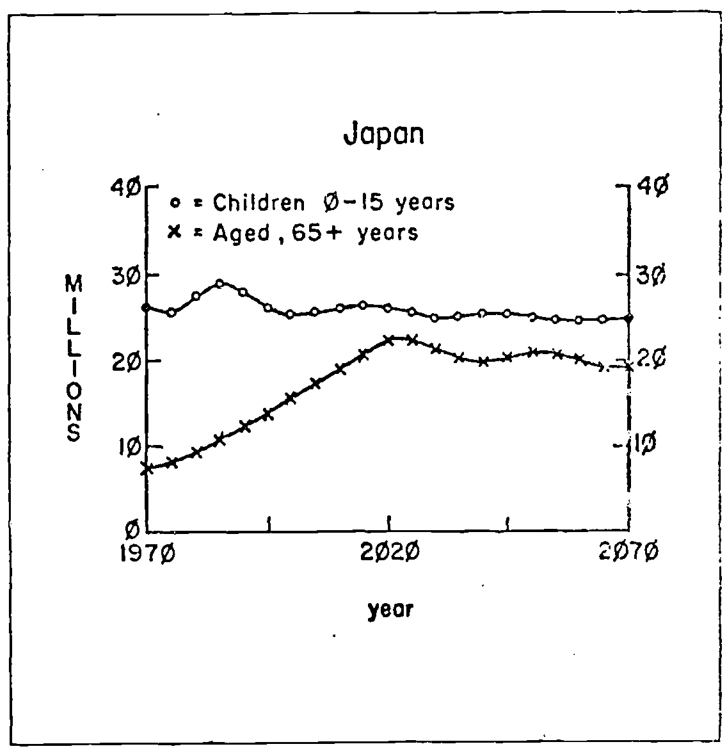
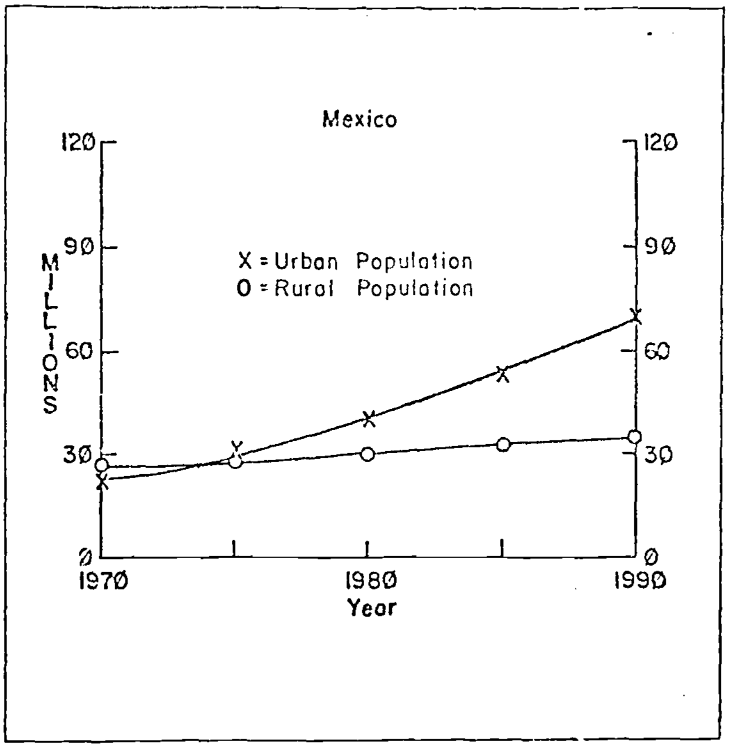
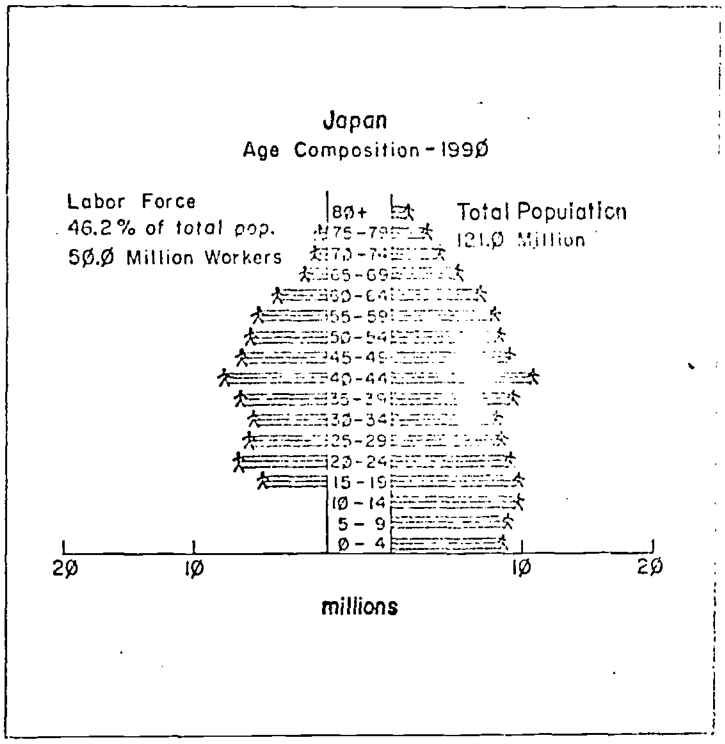


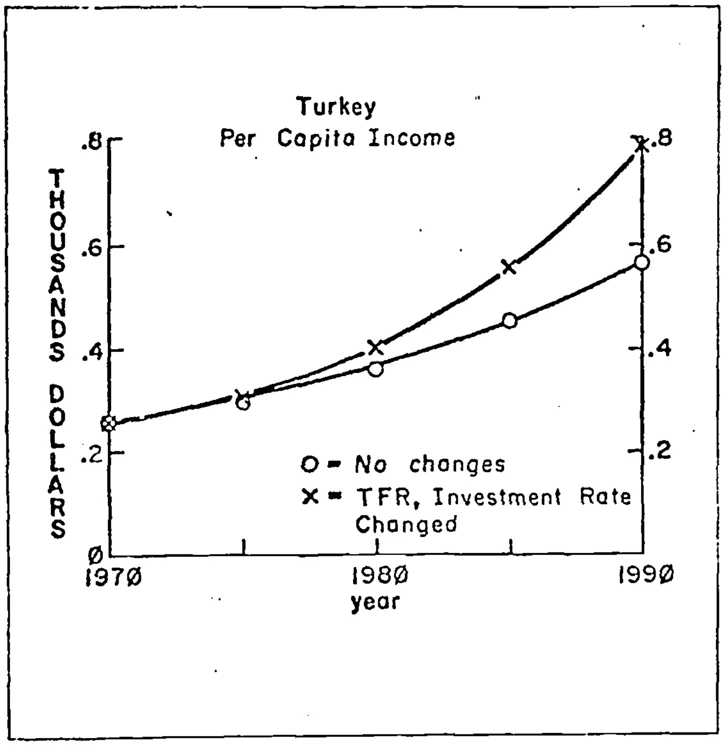
Frame 4



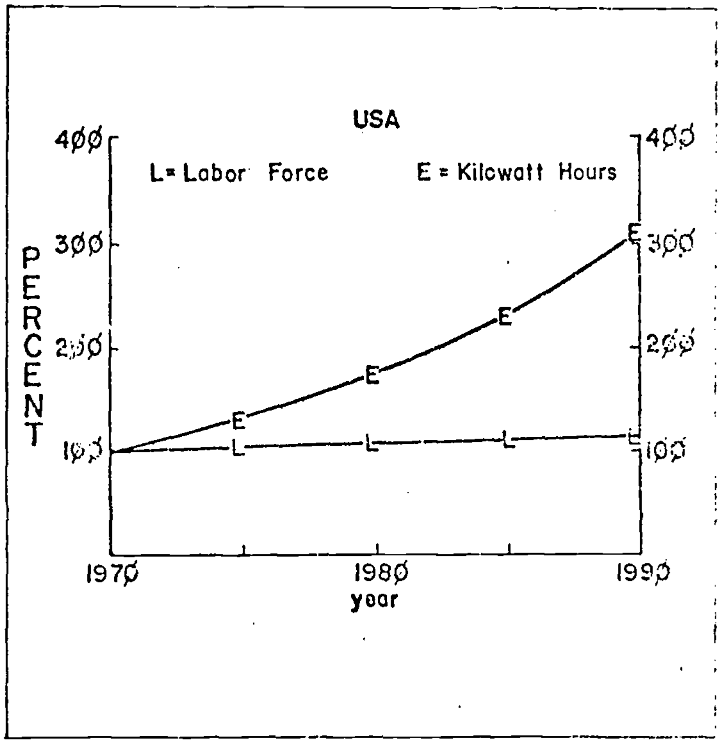
Frame 5



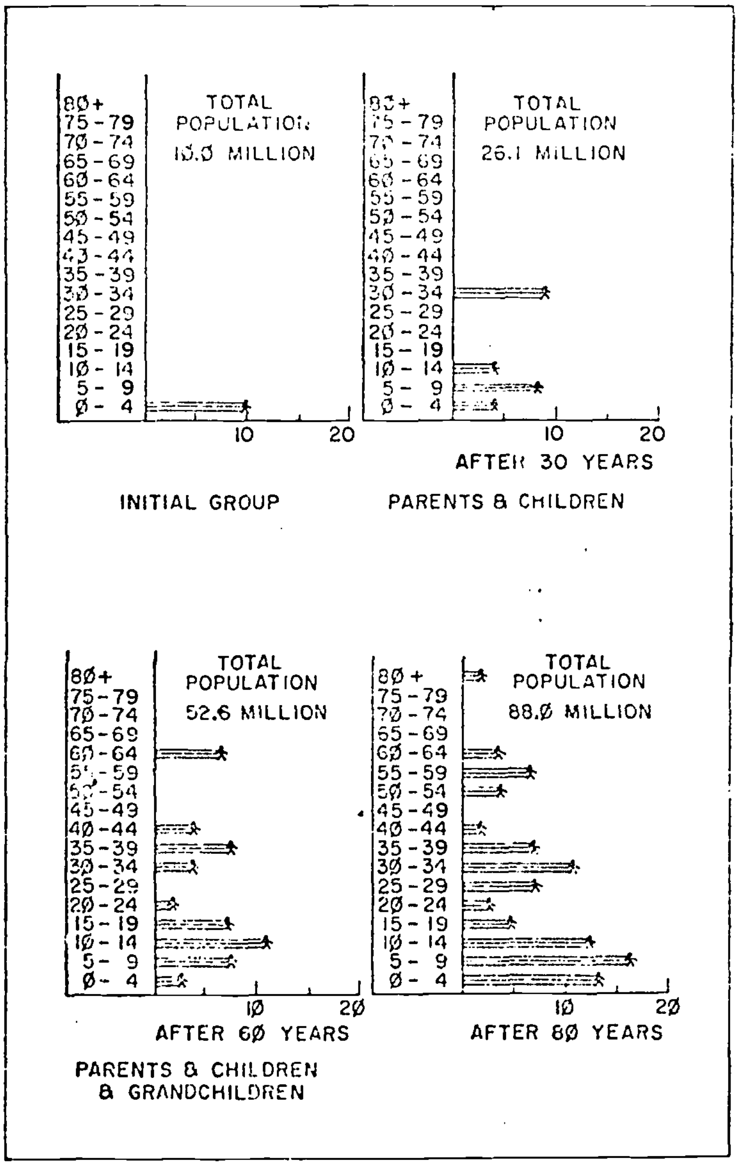
Frame 6



Frame 7



Frame 8



Frame 9

Frame 9 shows some aspects of the basic mechanisms of population projections. It illustrates how a hypothetical cohort of 10 mil. babies will grow over time. The projection can be made under various fertility and mortality rates. Emergence of new generations and phasing out of older generations are simulated.