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TEMPO
GENERAL ELECTRIC
CENTER FOR ADVANCED STUDIES
SANTA BARBARA, CALIFORNIA
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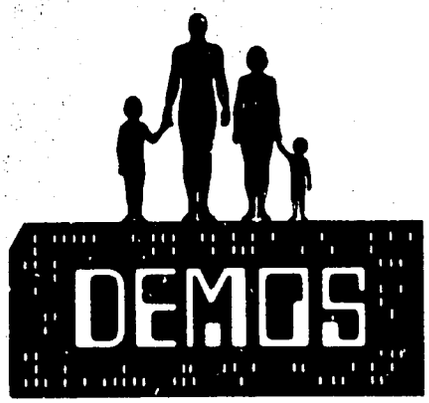
Description of the Economic-Demographic Model, James P. Bennett, Richard A. Brown, William E. McFarland, Revised Edition, June 1972 (68TMP-120 Revised).

Population Growth and Economic Development: Background and Guide, James P. Bennett, Stephen Enke, Revised Edition, June 1971 (71TMP-4(Revised).

PREFACE



Demos, the Greek name for *the people* viewed as a social, political, and economic unit, characterizes what the DEMOS manual and computer program are designed to do—to provide tools for understanding important links between the demographic characteristics of a people and the economic and political dimensions of the societies in which they live, will live, or would like to live. In particular, DEMOS is designed primarily to assist people with varying backgrounds in demography and economics to better understand how projection techniques can be used to anticipate future demographic developments and their impacts on the socioeconomic context of government policy-making.

One of the salient features of DEMOS is the active involvement of students. The text is interspersed with exercises and questions designed to review and use new materials before moving on to succeeding sections. In fact, the ultimate objective of the program is to permit students to teach themselves. At the present stage of development, however, the assistance of a well-trained instructor is essential at key points. Most students will require additional explanation and supplemental reading to fully understand some of the underlying economic and demographic principles and theories.

The DEMOS materials have considerable flexibility. The basic set of data used in the exercise projections can be altered from one instructional situation to another. For example, all or part of the standard demographic and economic data supplied with the DEMOS program can be replaced by other data to better fit a particular country or region.

The manual is ideally used where students have ready access to remote computer terminals that they can utilize at their own convenience, outside of class, and at their own speed. Many of the exercise projections may either be run concurrently with the reader's progress through the manual or run in advance by the instructor for distribution at the appropriate time.

DEMOS can also be used with batch processing, making the program adaptable for many settings outside the United States that lack the time sharing hardware. In this mode it is desirable for the instructor to run

more of the projections in advance, to spend more time structuring runs, and to place more emphasis on collective interpretation of results in class. DEMOS also has been designed to run on medium-size computers, which are available throughout much of the world. Finally, the TEMPO staff welcomes questions on how the materials might be adapted to specific situations.

A DEMOS workbook has been prepared to assist the reader to do the exercises. The workbook includes worksheets to assist in drawing graphs, hints and answers to many of the exercise questions, and other supplementary materials.

The DEMOS computer program, manual, and workbook were prepared under contract to the Agency for International Development, U.S. Department of State. The monitor of this contract was Mr. Carl Hemmer. Overall supervision of the work was the responsibility of Dr. William E. McFarland. Many members of the TEMPO staff have been involved in the design and writing of the DEMOS package. Drs. David Holmes and William McFarland originally conceived DEMOS and are the principal authors of Chapters 1 and 2. Chapter 3 is taken almost entirely from a previous TEMPO publication, *Description of the Economic-Demographic Model,** of which Dr. McFarland is the principal author. Chapter 4 is primarily the work of Mr. John Palmisano and Dr. Holmes. Chapter 5 was written mainly by Mr. V.S. Badari. Chapter 6 is the work of Mr. Henry Cole and Dr. Holmes, and Chapter 7 belongs to Mr. Cole and Dr. McFarland. The computer program represents the joint efforts of Mr. Richard Brown and Mr. Palmisano.

*68TMP-120, General Electric–TEMPO, Santa Barbara, 1968.

CONTENTS

PREFACE iii
LIST OF ILLUSTRATIONS vii
LIST OF TABLES viii

PART I. DEMOGRAPHIC PROJECTION AND ANALYSIS
Introduction to Part I I-1

Chapter 1 INTRODUCTION TO POPULATION PROJECTION AND ANALYSIS (18 pages) 1-1
Introduction 1-1
The Population Pyramid 1-2
Population Cohorts, by Age or Date of Birth 1-4
Unraveling Demographic History from the Population Pyramid 1-5
How the Current Pyramid Helps Shape the Demographic Future 1-9
The Impact of Age Composition on World Population Growth 1-10
Tracing the Dynamic Impacts of Changes in Fertility and Mortality on Age Composition 1-11

Chapter 2 AGE-SEX COMPOSITION AND THE DEMOGRAPHIC FUTURE (18 pages) 2-1
Population Projections 2-1
Incorporating Age and Sex Composition 2-3
The Mechanics of Projections with Age- and Sex-Specific Parameters 2-4
Description of the Population Projection Mode 2-9
Computer Exercises on Population Projections 2-11
Momentum 2-14
Zero Population Growth (ZPG) 2-17

Chapter 3 STABLE POPULATION TECHNIQUES (13 pages) 3-1
Introduction 3-1
Characteristics of Stable Populations 3-1
Regional Model Life Tables and Stable Populati... 3-2
An Illustrative Application of Stable Population Techniques 3-3

(Continued)

CONTENTS (continued)

PART II. EDUCATION AND MANPOWER
Introduction to Part II II-1

Chapter 4 THE IMPACT OF DEMOGRAPHIC CHANGE ON THE DEMAND FOR EDUCATION (14 pages) 4-1
Introduction 4-1
Projecting Student Enrollments 4-2
Projecting Teacher Requirements 4-5
Projecting the Costs of Education 4-12

Chapter 5 THE IMPACT OF DEMOGRAPHIC CHANGE ON THE LABOR FORCE AND UNEMPLOYMENT (11 pages) 5-1
Introduction 5-1
The Age Composition and the Dependency Ratio 5-1
Labor Force: Definition and Measurement 5-3
Labor Force Participation Rates 5-3
Projecting the Labor Force 5-3
Labor Force and Unemployment 5-7
Population Growth and Unemployment 5-9

PART III. RELATING DEMOGRAPHIC CHANGE TO ECONOMIC DEVELOPMENT AND PUBLIC EXPENDITURE
Introduction to Part III III-1

Chapter 6 THE AGGREGATE ECONOMIC MODEL (18 pages) 6-1
Introduction 6-1
Key Economic Variables 6-1
Description of the Economic Model 6-3
Response of Economic Projections to Demographic Change 6-12

Chapter 7 GOVERNMENT EXPENDITURES AND THE IMPLIED TRADEOFFS (16 pages) 7-1
Introduction 7-1
The Government Sector 7-2
Tradeoffs 7-8
Tradeoffs within the Government Budget 7-11

ILLUSTRATIONS

Figure No.	Titl_	Page
1-1	Numerical and relative pyramids.	1-3
1-2	Following a cohort through time (numerical pyramids).	1-4
1-3	USSR numerical population pyramid in 1959.	1-5
1-4	U.S. numerical population pyramids.	1-8
1-5	Population echo effect.	1-9
1-6	Effect of continued high fertility and declining mortality on population growth.	1-10
1-7	Population profiles for a one-shot reduction in fertility.	1-12
1-8	Population profiles for a permanent reduction in fertility.	1-13
1-9	Fertility declines for 25 years, beginning in 1970 and then stabilizes.	1-14
1-10	Population profiles for a continuing reduction in fertility.	1-15
1-11	The effect of declining infant mortality on the base of the pyramid.	1-16
2-1	Population growth rate in relation to the crude birth rate and crude death rate.	2-2
2-2	A simple age-specific projection.	2-5
3-1	Contrast of reported female age distribution and age distribution computed for mortality level 15.	3-7
4-1	Flow of student enrollments.	4-3
4-2	Teacher requirements with changing fertility and constant student-teacher ratio assumptions.	4-6
4-3	Teacher requirements with changing fertility and changing student-teacher ratio assumptions.	4-8
5-1	Age distribution and child dependency ratio (D) with a decline in fertility.	5-2
5-2	Average male participation rates by age for agricultural and industrialized countries.	5-4
5-3	Average female participation rates by age for agricultural and industrialized countries.	5-4

(Continued)

ILLUSTRATIONS (continued)

Figure No.	Title	Page
5-4	Projected labor force for Developa under constant and declining fertility assumptions.	5-5
5-5	Additional jobs required under constant fertility and declining fertility assumptions.	5-6
5-6	Ratio of labor force to population for Developa under constant and declining fertility.	5-7
6-1	Flowchart of basic computer sequence.	6-4
6-2	Growth rates of capital, GNP, and employment.	6-10
6-3	GNP per capita, constant and declining fertility assumptions.	6-13
6-4	Projections of the ratios of employment/population, capital/employment, and GNP/capital under constant and declining fertility assumptions.	6-14
7-1	Effect of increasing education enrollment targets on the education and "other" budgets, assuming constant fertility and mortality.	7-12

TABLES

Table No.	Title	Page
3-1	Hypothetical demographic data.	3-4
3-2	Deriving cumulative age distributions	3-5
3-3	Mortality level calculation results.	3-6
3-4	Cumulative female age distributions for mortality levels 15, 17, and 15.8.	3-8
3-5	Male and female population distribution.	3-9
3-6	Survival rates.	3-10
3-7	Estimating age-specific birth rates.	3-11
4-1	Educational budgets for three hypothetical countries.	4-13
5-1	Labor force participation rates.	5-5
5-2	Changes in the unemployment rate.	5-8
7-1	Plausible government expenditures as a percent of GNP for a developing country.	7-2

DEMOGRAPHIC PROJECTION AND ANALYSIS

INTRODUCTION TO PART I

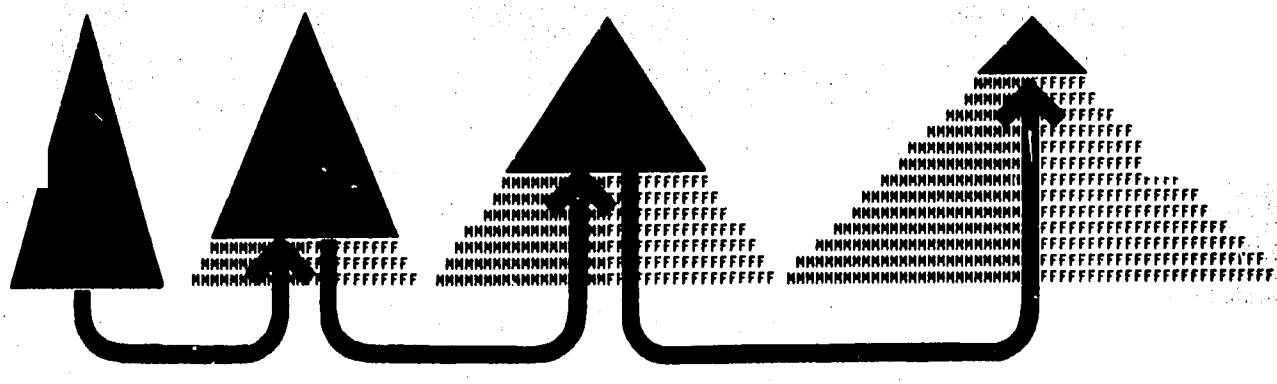
An understanding of the basic characteristics of a population—such as its size and rate of growth, age and sex composition, and underlying fertility and mortality conditions—is crucial to many aspects of public policy-making. As these characteristics change over time, the kinds of social services offered by the government and the size and composition of the total output of the economy must change as well. Existing demographic patterns have a built-in momentum, making it difficult to alter a demographic path in the short run. This increases the need and the ability of the social planner to anticipate changes. If demographic changes are anticipated sufficiently in advance, ther the costs of demographic transition can be reduced—an important goal of social planning.

Chapter 1 provides an introduction to demographic projection and analysis through an extensive discussion of how the population pyramid—a graphic display of the age and sex composition of a population—can be used to interpret past demographic experience and to anticipate future trends. Chapter 2 introduces basic population projection techniques. The chapter gives examples and experiments designed to show the manner in which the age distribution of a population affects the response of the population to change in mortality and fertility conditions. Chapter 3 introduces stable population techniques as a means of supplementing incomplete data for demographic analysis. This chapter is more technical than the previous two and it may be skipped on the initial reading.

Concepts in the DEMOS manual build upon each other, so the sequence of presentation is quite important. However, students with different backgrounds may want to spend different amounts of time in different areas. People with substantial demographic training should find much of Part I quite familiar, while others may find this part the most challenging.

CHAPTER 1

INTRODUCTION TO POPULATION PROJECTION AND ANALYSIS



INTRODUCTION TO POPULATION PROJECTION AND ANALYSIS

INTRODUCTION

From several different perspectives, the age and sex composition of the population represents one of the most important elements of demographic projection and analysis. Accordingly, this first chapter gives primary emphasis to the age and sex composition of the population, how it is depicted, and what it implies.

The age composition of a population is a reflection of the underlying demographic conditions of the preceding decades. For example, a population with a large proportion in the youngest ages is evidence that recent fertility rates have been relatively high. A uniform age distribution of the population is evidence of long-standing conditions of low fertility and mortality.

The composition of a population is also a major determinant of the manner in which underlying demographic conditions will affect the growth of the population. The present demographic conditions in the United States produce a natural growth rate (ie, excluding the growth that results from net immigration) in excess of 0.5 percent per year. If age-specific fertility and mortality rates remained at their present levels, however, the changing age and sex composition would eventually result in a slowly declining population size.

The present and future compositions of the population also represent major determinants of the socioeconomic implications of the population and its future growth. Most public programs serve different age and sex components of the population. Education serves primarily the young. Maternal care programs serve mainly females between the ages of 15 and 25. Other health programs serve primarily the elderly. Finally, the manner in which a given population growth affects the growth of total production is largely dependent upon the growth of the work-age component of the population.

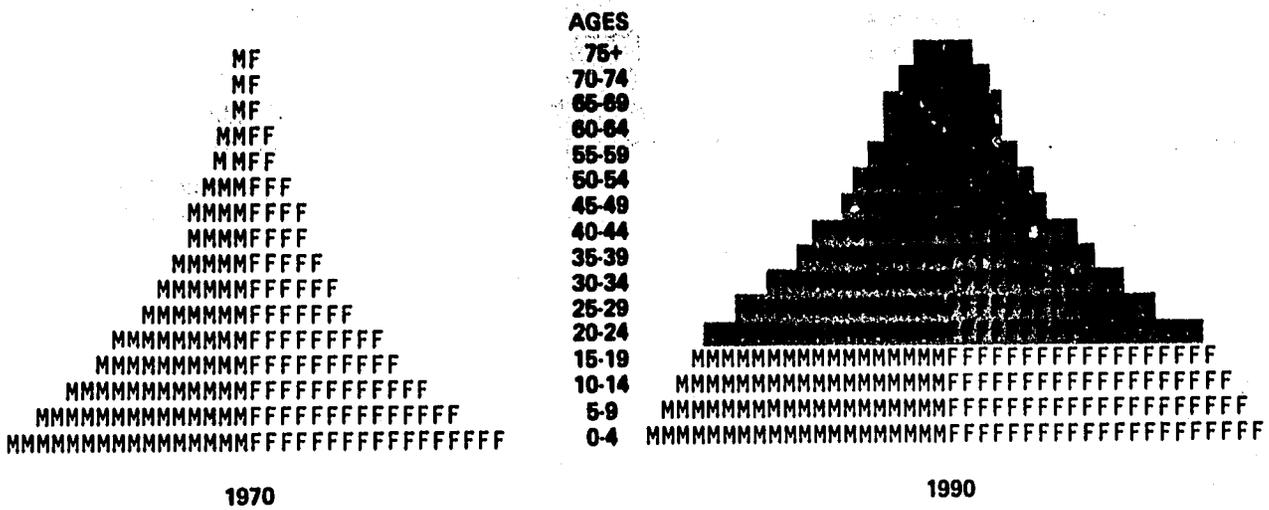
Given the important role of age and sex composition of the population, the first demographic tool to be discussed is the population pyramid, which is a commonly used graphic representation of a population's age and sex composition.

THE POPULATION PYRAMID

The population pyramid is a graph of the population distributed according to age and sex. Two basic kinds of pyramids are used. The first type, a *numerical* pyramid, plots *numbers* of people in each age and sex group, and the second, a *relative* pyramid, plots the *percentage distribution* of people according to age and sex. By convention, males are plotted on the left and females on the right. These are portrayed in Figure 1-1. Both types of pyramids are used in this text, but only the relative pyramid is used in the computer experiments.

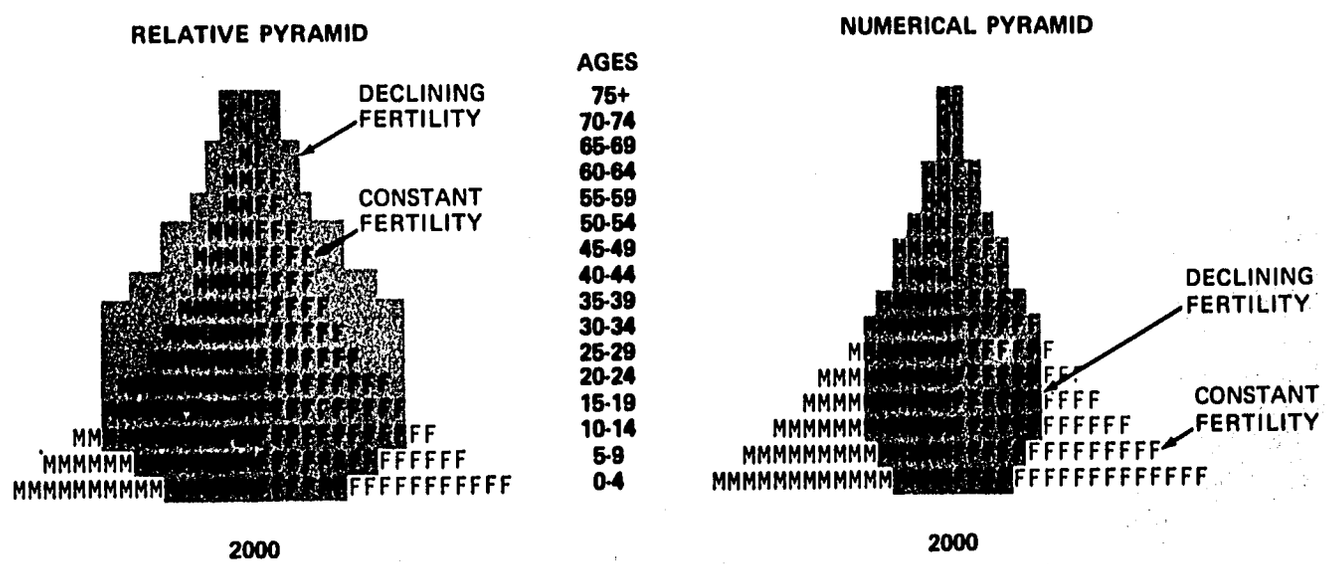
The major difference between the two kinds of pyramids is that the numerical pyramid increases in area as the population grows, while the relative pyramid always maintains a constant area of 100 percent. Panel A of Figure 1-1 shows how the area of the numerical pyramid typically changes as a population grows under conditions of constant fertility and mortality.

Because of the growth of the numerical pyramid, the shapes of the two types of pyramids may appear to respond differently to changes in underlying demographic parameters. Panel B of Figure 1-1 shows the impact by the year 2000 of a fertility decline on the same initial population using both numerical and relative pyramids. For each type of pyramid, the outline of the pyramid that results from declining fertility is superimposed on the pyramid resulting from constant fertility. In the case of the numerical pyramid, declining fertility shrinks the base while leaving the upper portion unchanged. In contrast, declining fertility shrinks the base of the relative pyramid and widens the top, since as the proportion of the young diminishes the proportion of older people in the population must increase. Thus, the two kinds of pyramids may appear to exhibit different dynamic characteristics.



PANEL A

How the numerical pyramid grows through time
(each M and F represents 100,000 people)



PANEL B

How the numerical and relative pyramids react differen
to the same fertility decline between 1970 and 2000

Figure 1-1. Numerical and relative pyramid

POPULATION COHORTS, BY AGE OR DATE OF BIRTH

The population of a given age is frequently called an age cohort.* When following an age cohort through time, it is useful to identify the cohort by date of birth. Thus, the cohort ages 0 through 4 at the beginning of 1970 consists of that part of the population born during the years 1965 through 1969. Twenty years later, in 1990, this group will be depicted as cohort ages 20 through 24. (This is illustrated in Figure 1-2.)

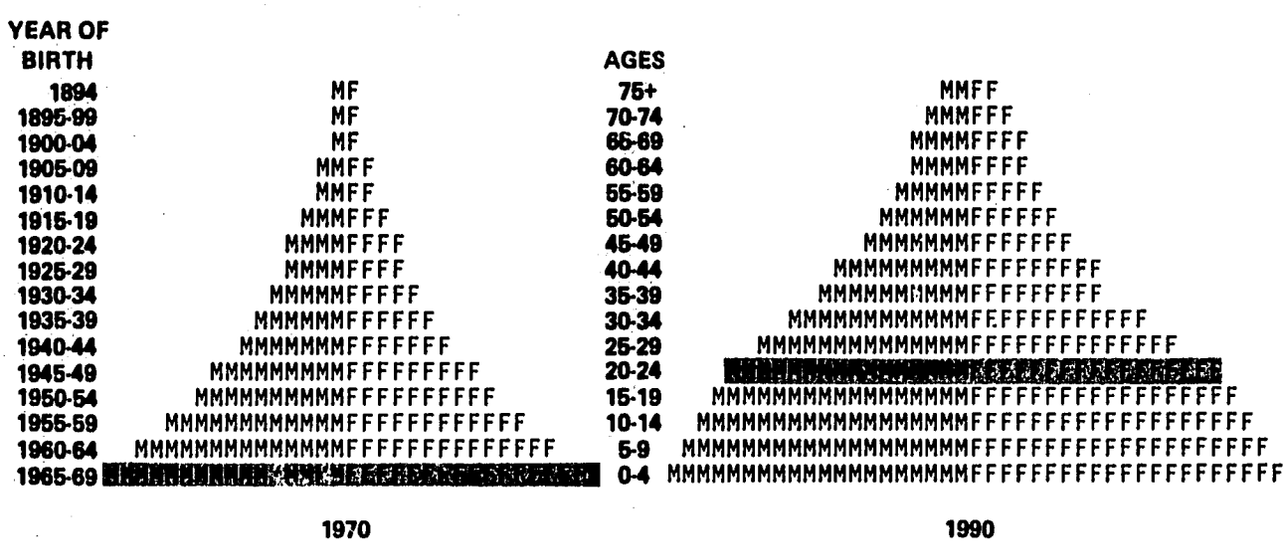


Figure 1-2. Following a cohort through time (numerical pyramids).

* The term "cohort" refers to a group within the population whose members possess a common characteristic, usually age or sex. In this text, the population is generally divided into age cohorts defined by a given 5-year interval, eg, 5 through 9 years.

UNRAVELING DEMOGRAPHIC HISTORY FROM THE POPULATION PYRAMID

Rapid and drastic changes in mortality or fertility weave characteristic patterns in the age-sex profile. The resulting bumps and indentations in the pyramid provide a historical record that can be interpreted by someone familiar with the dynamics of population pyramids.

Take, for example, the profile of the Russian population in 1959 shown in Figure 1-3. Few pyramids show such dramatic distortions as this one, making it especially interesting for analysis.

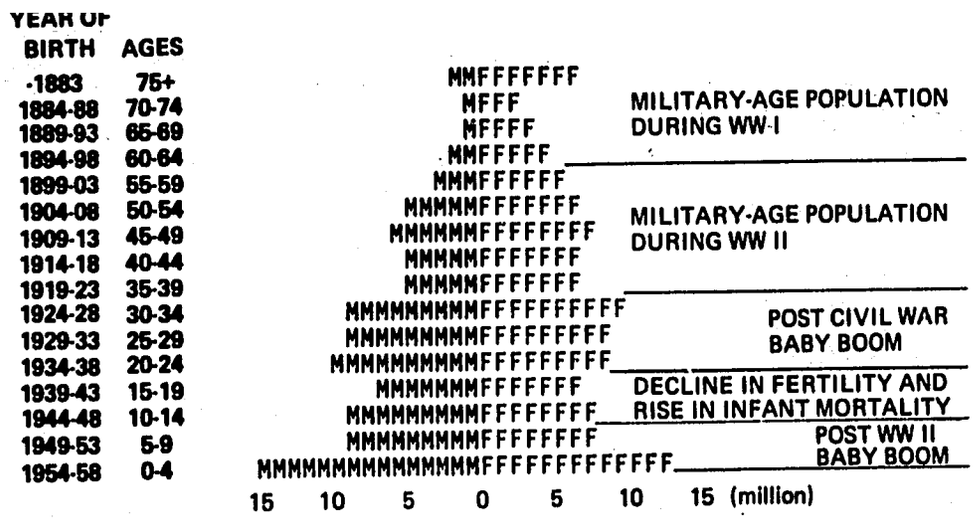


Figure 1-3. USSR numerical population pyramid in 1959.

The Russians are estimated to have lost more than 20 million people during World War II, representing more than a tenfold increase in mortality compared to the prior decade. Since this change in mortality was age and sex selective, it caused substantial modifications in the shape of the population pyramid. In Figure 1-3, the drastic reduction in the size of the 1959 pyramid above age 35 shows that adults suffered relatively more casualties than children in World War II. Also, adult men suffered more deaths than adult women. Note in Figure 1-3 that males ages 35 to 44 were the hardest hit of any group. These males were in the prime draft ages of 17 to 26 at the time of the German invasion in 1941.

With a large proportion of the young men away from home for an extended period, fewer babies were born. The indentation in the pyramid corresponding to ages 15-19 (born 1939-43) indicates such a fertility decline.

Some of this gap may also have been caused by an increase in infant mortality. The effects of these two phenomena (ie, declining fertility and increasing infant mortality) are indistinguishable in the graph.

Ten years after the end of the war, the base of the pyramid began to expand substantially. A large part of this "baby boom" was caused by the shape of the age distribution. The people born during the earlier baby boom, following the decade of turmoil after World War I, were in their prime fertile years in the 1950s. So, in addition to each couple tending to have more children than before, relatively more of the population was concentrated in the 20 to 34 age group. The result was the 1955-59 baby boom.

Similarly, population pyramids can be used to predict the future as well as to interpret the past. Before turning to a discussion of age distribution and demographic projection analysis, however, it will be useful to review the lessons learned so far in some brief exercises with population pyramids.

Exercise 1-1

1. Why doesn't the area of the relative pyramid increase as the population grows?

2.@ Plot the following age-sex distributed population* in both a relative pyramid and a numerical pyramid.

Age	Males (number)	(%)	Females (number)	(%)	Total (number)
0-4	353	9	346	9	699
5-9	292	7	288	7	580
10-14	246	6	244	6	490
15-19	210	5	208	5	418
20-24	177	4	176	4	353
25-29	149	4	148	4	297
30-34	123	3	124	3	247
35-39	103	3	104	3	207
40-44	85	2	86	2	171
45-49	69	2	72	2	141
50-54	55	1	58	1	113
55-59	44	1	48	1	92
60-64	32	1	35	1	67
65+	48	1	62	2	110
Total	1986		1999		3985

3. Show what would happen in each pyramid if half of the people ages 20 to 39 died tomorrow.

@ This symbol indicates that a worksheet is available in the accompanying Workbook to aid in completing the exercise.

These data are from Developa, a hypothetical high-fertility and high-mortality countr that will be used frequently for illustration.

4. In Figure 1-4, locate on the 1970 pyramid the cohort of males that were ages 15 through 19 in 1950. How old are these men in 1970?

5. Beside each of the two U.S. pyramids shown in Figure 1-4, write the birth dates of each cohort in the right- and left-hand margins.

6. What demographic events might have caused (a) the bulge in the 1970 age distribution between ages 5 and 24, and (b) the indentation between ages 30 and 39?

```
                          AGES
     MMMMFFFFFFF          65+        MMMMMMMMFFFFFFFFFFFF
      MMMFFF              60-64          MMMMFFFFF
     MMMMFFFF             55-59         MMMMMFFFFF
     MMMMFFFF             50-54         MMMMMFFFFFF
     MMMMFFFFF            45-49        MMMMMMFFFFFF
    MMMMMFFFFF            40-44        MMMMMMFFFFFF
    MMMMMFFFFFF           35-39         MMMMMFFFFF
   MMMMMMFFFFFF           30-34        MMMMMMFFFFF
   MMMMMMFFFFFF           25-29       MMMMMMMFFFFFFF
   MMMMMMFFFFFF           20-24      MMMMMMMFFFFFFFF
    MMMMMFFFFF            15-19    MMMMMMMMMFFFFFFFFF
   MMMMMMFFFFF            10-14   MMMMMMMMMMFFFFFFFFFF
  MMMMMMMFFFFFFF          5-9     MMMMMMMMMMFFFFFFFFFF
MMMMMMMMFFFFFFFF          0-4      MMMMMMMMMFFFFFFFF

      1950                                1970
```

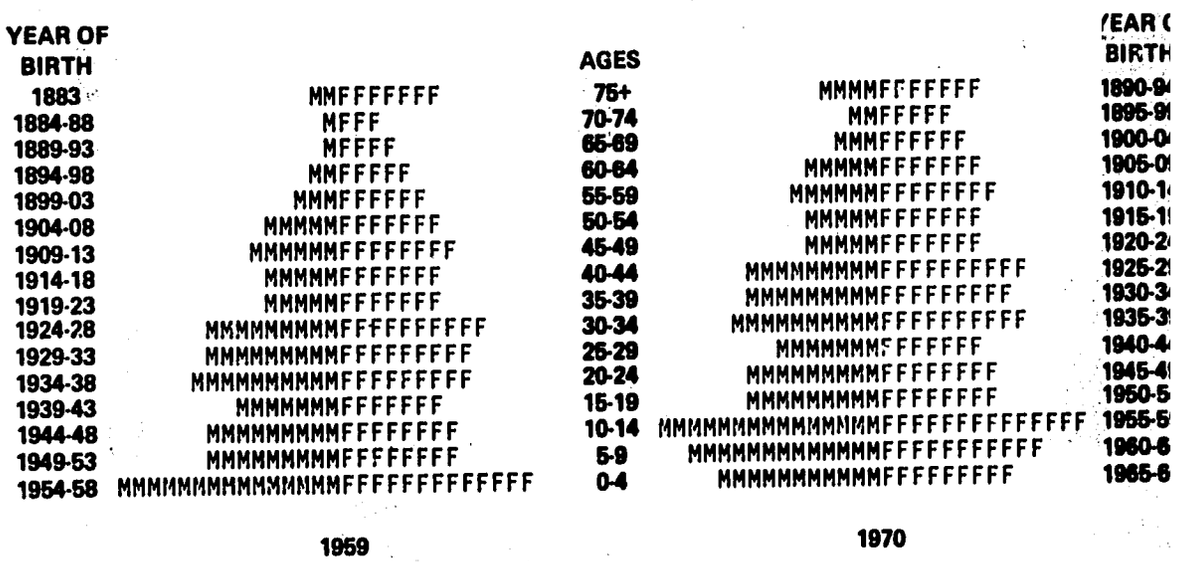
(each M and F represents 1,000,000 people).

Figure 1-4. U.S. numerical population pyramids.

HOW THE CURRENT PYRAMID HELPS SHAPE THE DEMOGRAPHIC FUTURE

Consider again the Russian pyramid presented in Figure 1-3. It was noted earlier that Russians born from 1924 through 1938 had reached their prime fertile years by 1959, reinforcing the upward trend in fertility. Thus a bulge in the age distribution, the legacy of a past baby boom, repeated itself after a 20- to 30-year lag.

Future *echo* effects of this nature can be anticipated by calculating when existing bulges or indentations in the lower part of the pyramid will reach the ages of highest fertility, normally ages 20-34. For example, it is apparent in Figure 1-5 that the echo effect of the post-World War II baby boom will tend to elevate the Russian crude birth rate in the late 1970's and the 1980's as members of the enlarged 10- to 14-year old cohort reach their twenties and early thirties. This will tend to counteract the current trend toward declining fertility.



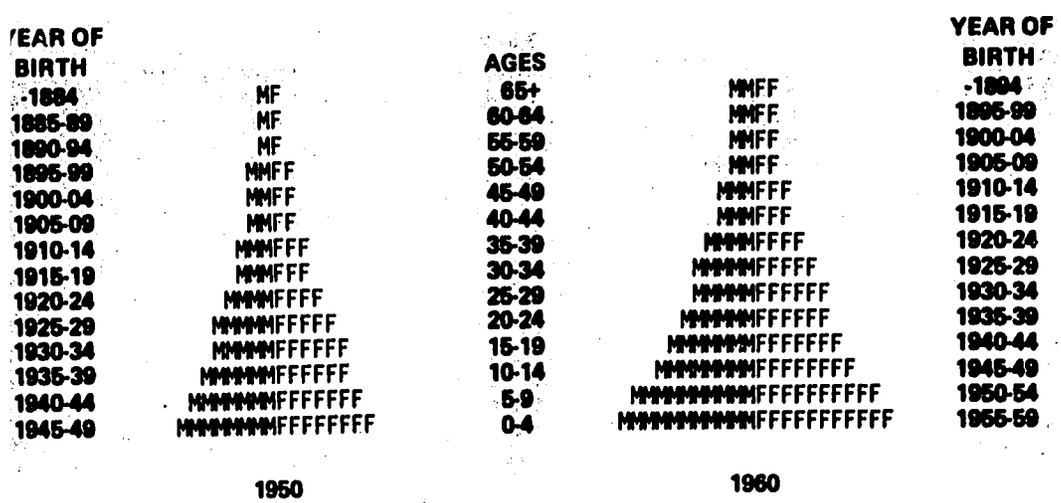
USSR POPULATION PYRAMIDS
(each M and F represents 1,000,000 people)

Figure 1-5. Population echo effect

THE IMPACT OF AGE COMPOSITION ON WORLD POPULATION GROWTH

Despite the sharp fluctuations introduced by three wars and a revolution in 30 years, even Russian demographic behavior, over the long run, has followed the broad demographic trends of other industrialized countries. Although fertility and mortality conditions have moved cyclically in response to changes in specific economic and social environments, the underlying trend has been for mortality and fertility to decline together slowly over approximately a century.

The bulk of the world's population, dwelling in the developing countries, has not followed this trend. Rather fertility remained constant at traditionally high levels, while mortality declined drastically after World War II, especially among infants and smaller children. The Brazilian population pyramid for 1960 shown in Figure 1-6 typifies the resulting age composition.



NUMERICAL PYRAMIDS FOR THE BRAZILIAN POPULATION

(each M and F represents 500,000 people)

Figure 1-6. Effect of continued high fertility and declining mortality on population growth.

This broad-based pyramid contains a special message about future population growth. As we have seen, declining fertility tends to shrink the base of the pyramid while simultaneously producing a bulge as the former base moves up the age distribution over time. When this bulge hits the fertile age range, it tends to counteract the effect of the fertility decline, as in the Russian example. Therefore, even though women may individually have

fewer babies, a greater percentage of the population is moving into its child-bearing years. Population growth will therefore remain higher during this transitional phase than it would have been had the age composition remained constant.

The term "momentum" has been used to describe this phenomenon, since the tendency for population growth to resist change is roughly analogous to the tendency of a physical body in motion to resist changes in its velocity and direction. Thus, the potential for momentum that lies in the broad-based pyramids of much of the world's population will unavoidably sustain world population growth at a relatively high rate over the next several decades.

TRACING THE DYNAMIC IMPACTS OF CHANGES IN FERTILITY AND MORTALITY ON AGE COMPOSITION

Distinctly different pyramid shapes result from different changes in underlying demographic conditions. Mortality change generally affects the pyramid differently than does fertility change if the change in mortality is not concentrated on infants and young children. A rise in infant mortality cannot be distinguished from a fall in fertility and vice versa. A change in the present shape of the pyramid also triggers a series of echo effects that gradually damp out in the long run, assuming an absence of continuing disturbances. Pyramid analysis is designed to reveal these interactions and involves (1) visualizing the impact of demographic change on the future shape of the population pyramid, and (2) deducing from a given pyramid the demographic changes in the past that could have caused the observed shape.

For this introductory analysis, changes to be analyzed are of three general types:

1. A one-shot reduction in fertility, followed by a return to the previous level
2. A permanent reduction in fertility
3. A continuing reduction in fertility.

Changes in Fertility

A One-Shot Reduction. An example of the effects of this kind of change is shown in Figure 1-7.* The pyramids shown in the figure are *relative* pyramids, showing percentage composition. For Figure 1-7, fertility is assumed to have been cut in half for the period 1960 through 1969 and then restored to its original level from 1970 to 2020. Even though the change in fertility is only temporary, the reverberations are felt far into the future, as shown in the figure.

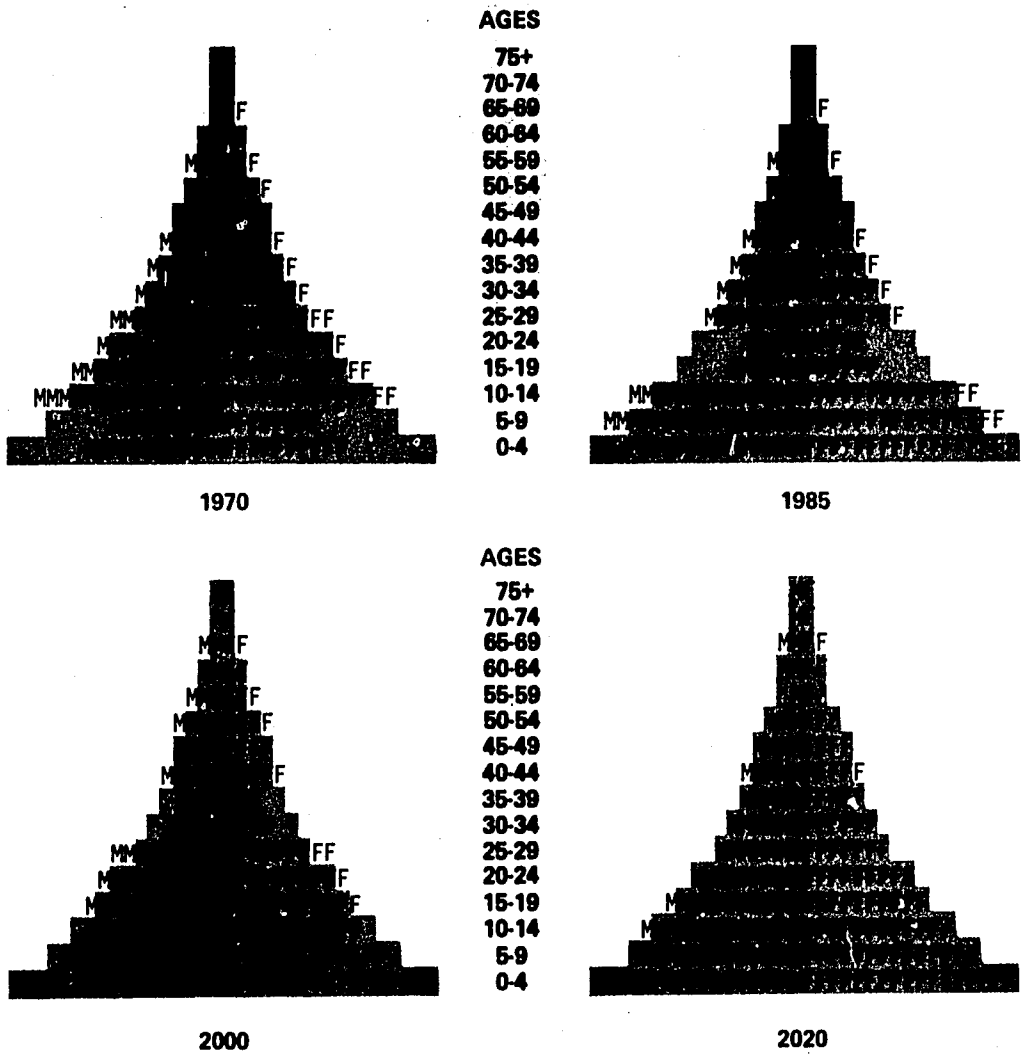


Figure 1-7. Population profiles for a one-shot reduction in fertility.

* To highlight the changes that occur in a given pyramid as the result of demographic change, the outline of the pyramid as it would have been under constant demographic conditions is superimposed on each altered pyramid.

A Permanent Reduction. In this example, fertility is cut by the same amount as in the previous example and allowed to remain at the lower level throughout the projection. Notice in Figure 1-8 that this change creates a "Christmas tree" shape in the pyramid that only begins to disappear in the final years of the projection, 50 years after the change. The changes produced in the One-Shot example are temporary and small by comparison. This underscores the need to examine the duration as well as the extent of the change in an underlying demographic parameter.

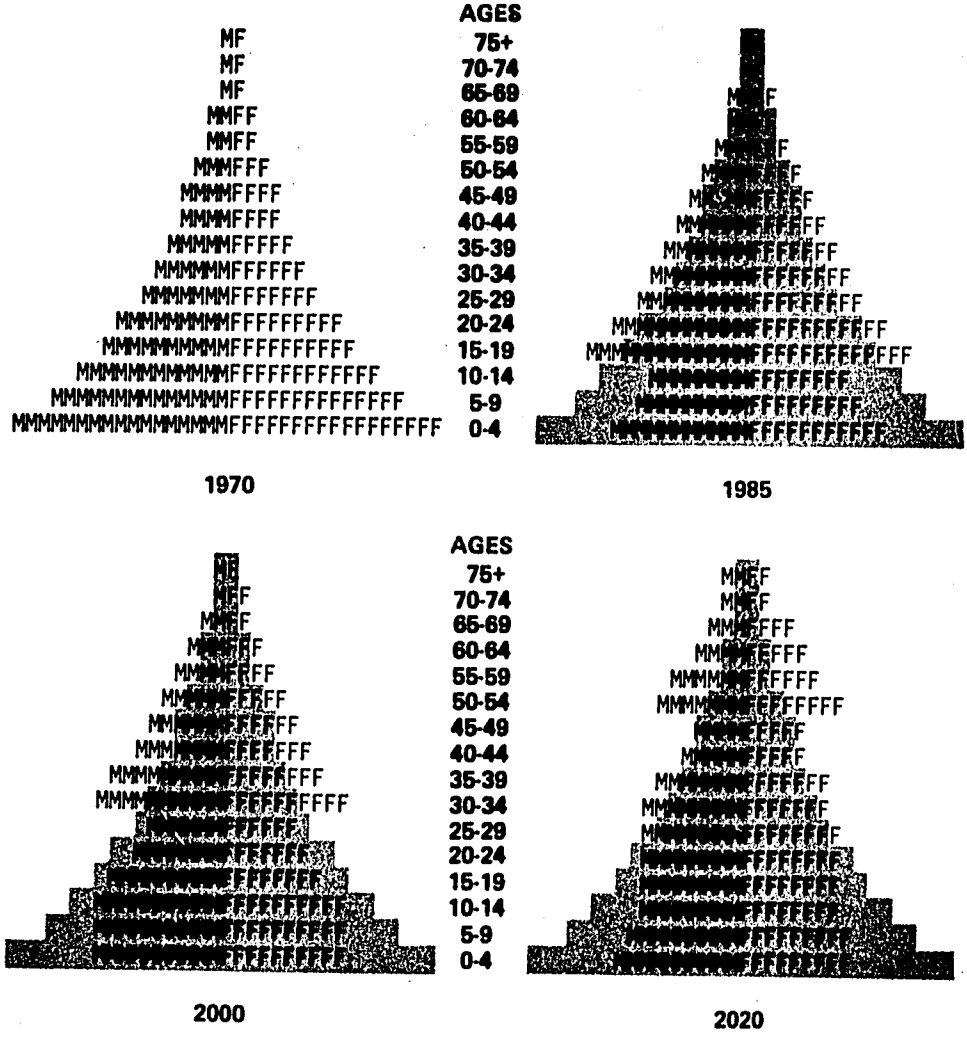


Figure 1-8. Population profiles for a permanent reduction in fertility.

If fertility declines and then levels off at a low level, the shape of the pyramid will eventually evolve into the characteristic bullet shape of the pyramids of modern industrialized countries, as shown in Figure 1-9.

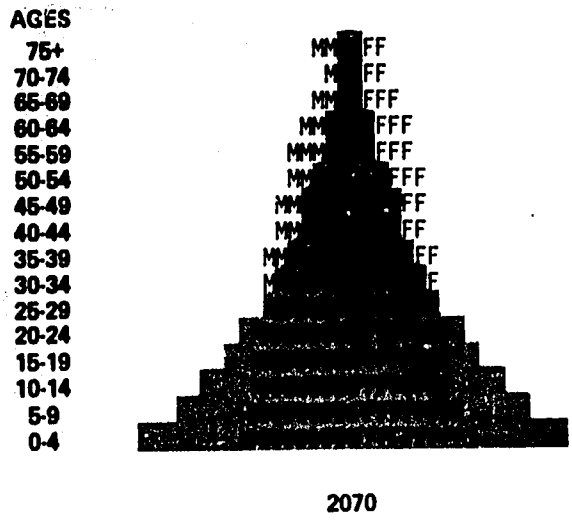


Figure 1-9. Fertility declines for 25 years, beginning in 1970, and then stabilizes.

A Continuing Reduction. In the final example, shown in Figure 1-10, fertility falls by the same amount as in the previous examples but the change occurs over a 50-year period rather than immediately. As a result, changes in the shape of the pyramid are much less dramatic than those resulting from the other types of changes.

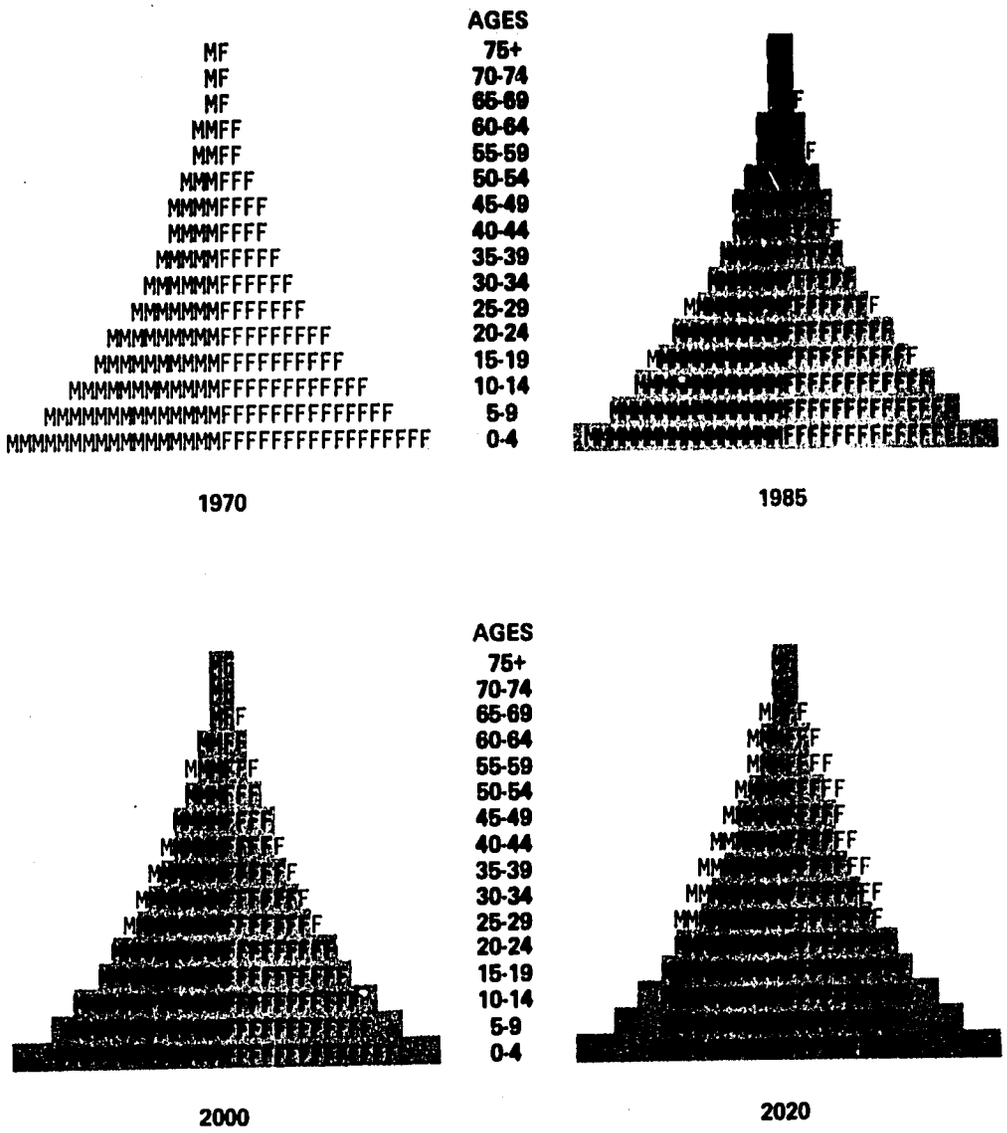


Figure 1-10. Population profiles for a continuing reduction in fertility.

The Impact of Changes in Mortality

Changes in mortality that affect all ages in a uniform manner are difficult to discern in population pyramids. Age-specific changes, however, leave a distinctive impact on pyramids.

In recent times, mortality among infants has declined much faster than for other age groups. This has the effect of broadening the base of the pyramid, as shown in Figure 1-11. (Recall also the case of Brazil, Figure 1-6.) If infant mortality were to increase, it would trigger the same kind of echo effects as caused by a fertility decline, described previously.

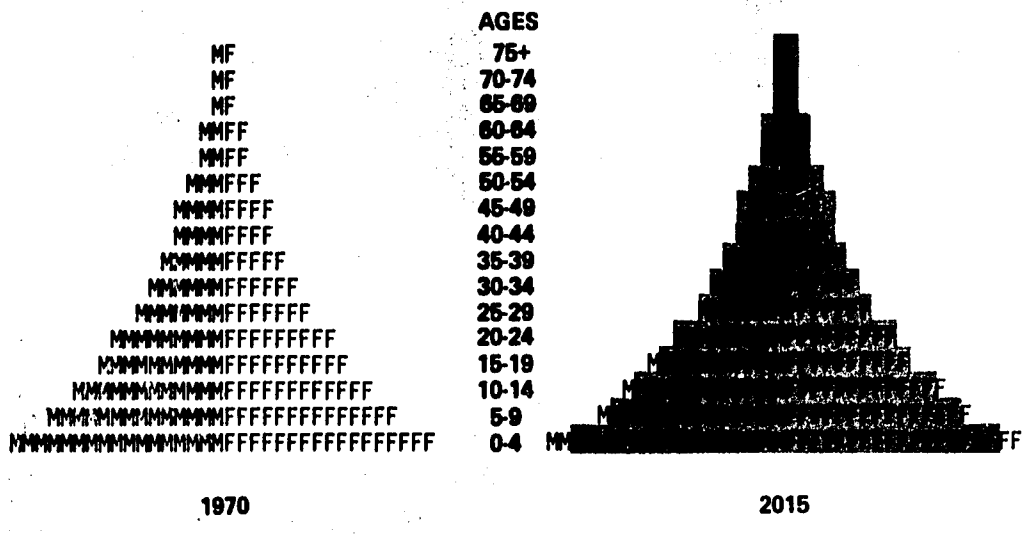
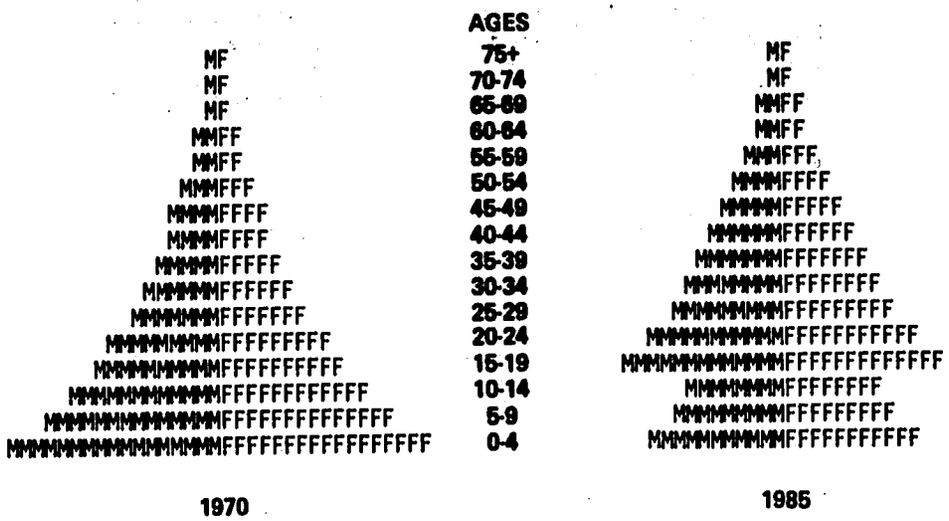


Figure 1-11. The effect of declining infant mortality on the base of the pyramid

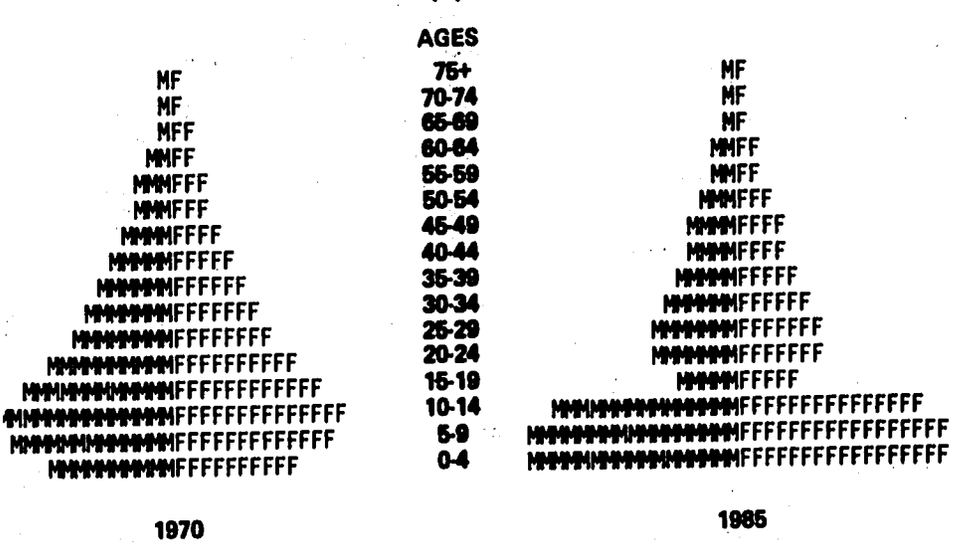
Exercise 1-2

Describe the changes in demographic parameters that might have caused the changes in the shapes of the following population pyramids, labeled (a), (b), (c), and (d).

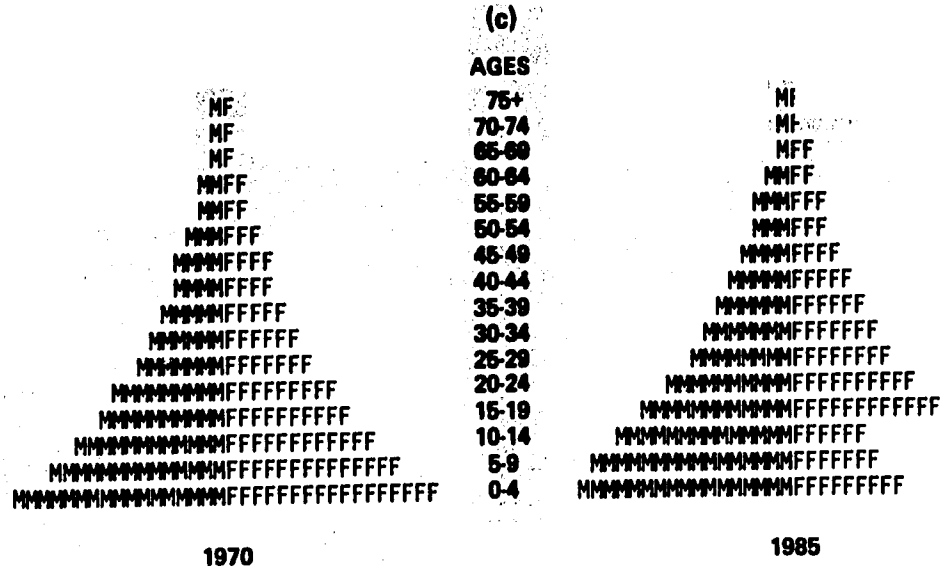
(a)



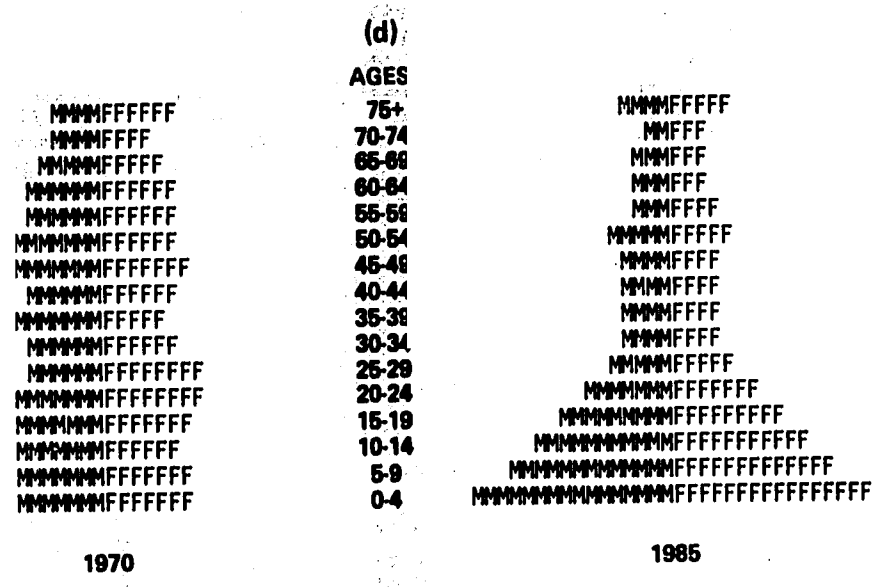
(b)



(c)



(d)



2.@ Draw population profiles for the year 2000 that will show the impact of the following demographic changes on the 1970 population profile (a) given in part 1 of this exercise:

a. A one-shot decline in fertility of 50 percent over an initial 5-year period

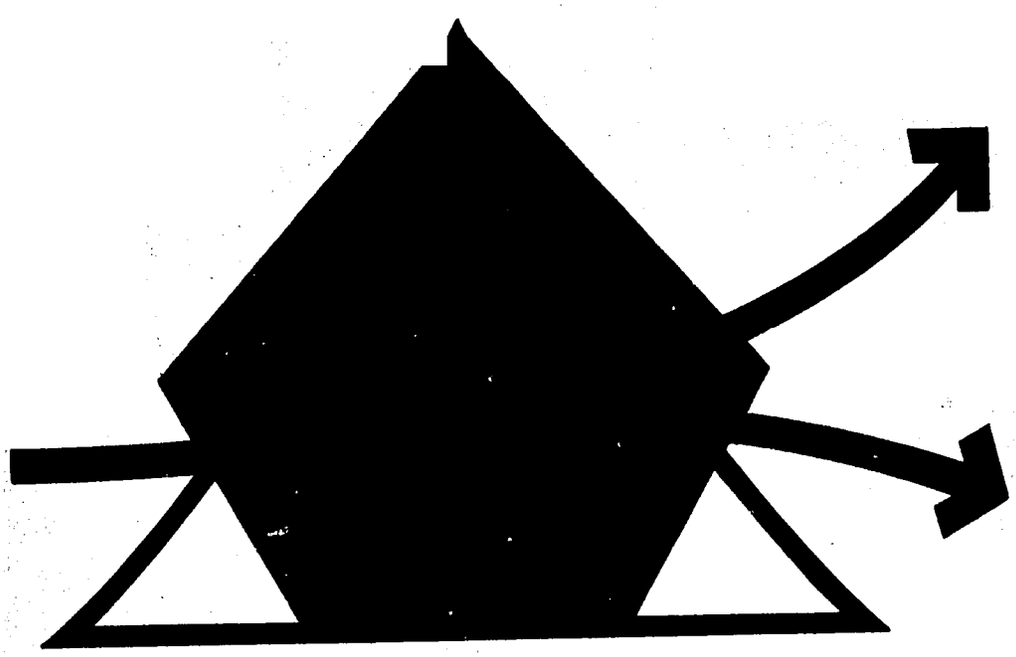
b. A permanent increase in fertility by 50 percent

c. A permanent decrease in infant mortality by 50 percent.

@ See worksheet in the Workbook.

CHAPTER 2

AGE-SEX COMPOSITION AND THE DEMOGRAPHIC FUTURE



AGE-SEX COMPOSITION AND THE DEMOGRAPHIC FUTURE

The discussion in Chapter 1 of the relationship of age-sex composition to population growth sets the stage for a more complete analysis of how these interactions relate to population projection techniques.

POPULATION PROJECTIONS

Without international migration, a country's population at the end of year t is equal to the population at the end of year t − 1 plus *births* minus *deaths* during the year. In algebraic terms,

$$POP_t = POP_{t-1} + BIRTHS_t - DEATHS$$

Dividing both sides of the equation by POP_{t-1} and rearranging terms, we have

$$\frac{POP_t - POP_{t-1}}{POP_{t-1}} = \frac{BIRTHS_t}{POP_{t-1}} - \frac{DEATHS_t}{POP_{t-1}}$$

The first term in the equation, $(POP_t - POP_{t-1})/POP_{t-1}$, multiplied by 100 is the population growth rate in percentage terms. The second and third terms multiplied by 1000 are the *Crude Birth Rate (CBR)* and *Crude Death Rate (CDR)*, respectively, ie, the number of births and deaths per 1000 population.* Therefore, the population projection equation can be restated as follows:

$$\text{Population Growth Rate} = (CBR - CDR) \div 10$$

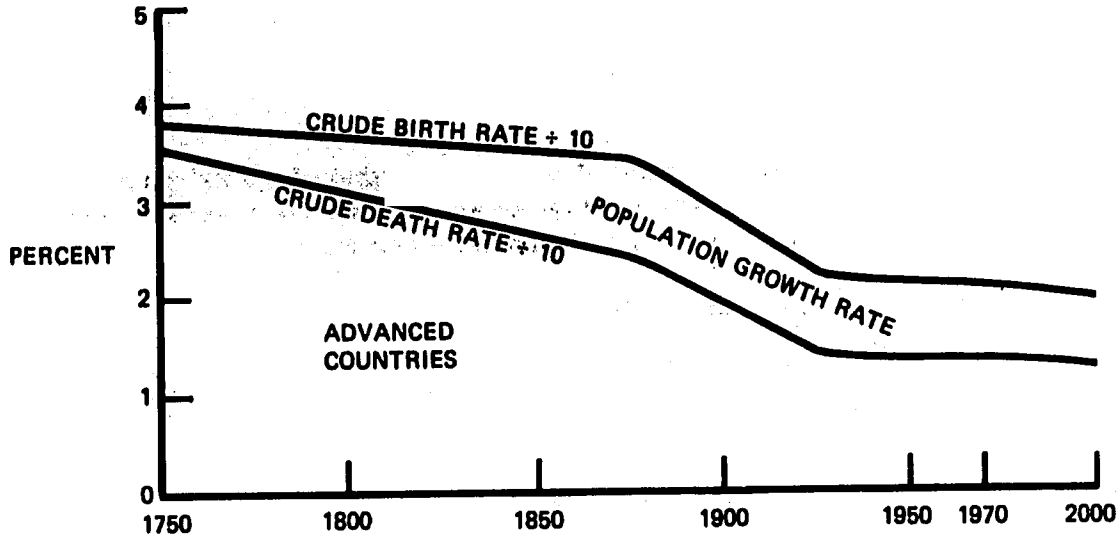
These relationships are shown graphically in Figure 2-1 for two sets of countries over the span of recorded demographic history.

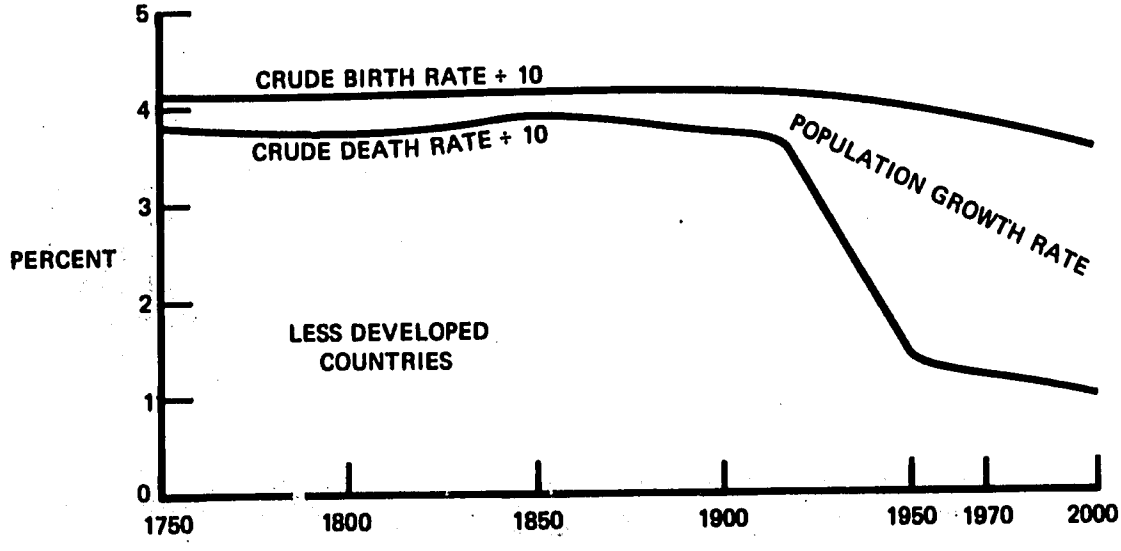
If CDR and CBR remain constant and we are only interested in population size, then the population growth rate is constant and population

* By convention these rates are usually expressed in per thousand terms rather than percentages, eg, 30 births per 1000 population rather than 3 per 100. Also, the mid-year population is normally used in the denominator of each fraction rather than the initial population as shown above.

projection is simple. Next period's population is equal to this period's population multiplied by one plus the constant population growth rate, r:

$$POP_t = (1 + r)\, POP_{t-1}$$





NOTE: Data for 1750 to 1900 are based on average estimates by Carr-Saunders-Wilcox, as modified by the U.N. in *The Determinants of Population Trends*. Estimated future growth rates based on U.N. population projections.

Figure 2-1. Population growth rate in relation to the crude birth rate and crude death rate.

When CDR and CBR are not constant, projection is not so simple. Since change in age composition is an important source of changes in CDR and CBR, projection analysis generally requires at least some disaggregation of the population by age.

INCORPORATING AGE AND SEX COMPOSITION

Crude birth and death rates change in response to changes in underlying fertility and mortality, modifying the population growth rate. Resulting changes in the age-sex composition of the population then have additional impacts on the growth rate and the crude birth and death rates.

Even if age-specific fertility and mortality rates remain constant, CBR and CDR will change if the age or sex composition of the population changes. This can be demonstrated with a numerical example. Suppose that the average number of births per thousand females of fertile age per year is 220 and that females of fertile age represent 20 percent of the total population. Then the crude birth rate is equal to 44 per thousand, ie, 0.20 times 220.

$$\text{CBR} = \frac{\text{births}}{\text{1000 population}} = \frac{\text{fertile-age females}}{\text{total population}} \cdot \frac{\text{births}}{\text{1000 fertile-age females}}$$

If the proportion of fertile females in the population falls from 20 percent to 15 percent, then the crude birth rate falls from 44 to 33 per thousand (ie, 0.15 X 220), even though the number of births per female of fertile age does not change. Given this dependence on age composition, the CBR and CDR have definite shortcomings as measures of fertility and mortality.

In the analysis of underlying demographic characteristics of a population, several measures of fertility, mortality, and population growth are therefore commonly used that are free from interactions with age composition. These are explained below.

Age-Specific Fertility Rates

These rates, which are normally calculated for each 5-year cohort of females of fertile age, represent the average number of births per year to a woman in the given age range; ie, if 100 women between the ages of 20-24 have an average of 30 live births per year, the age-specific birth rate for the cohort 20-24 is equal to 0.30.

Age-Specific Mortality Rates

These rates represent the proportion of a given age cohort to die within 1 year.* Thus, if 1 percent of the population ages 20-24 at the beginning of the year die by the end of the year, the mortality rate for this age group is 0.01. Since mortality may differ substantially between males and females of the same age, mortality rates are usually both age-specific and sex-specific.

Infant Mortality Rate

The "infant mortality rate"† defined here is the proportion of births during a year to die before the end of the year. The survivors comprise the population at the beginning of the next year under the age of one.

THE MECHANICS OF PROJECTIONS WITH AGE- AND SEX-SPECIFIC PARAMETERS

To illustrate the use of age- and sex-specific parameters in makind population projections, consider projection 1 year hence the female population under the age of 5. The same method applies to older ages.

The female population of age 4 one year hence is comprised of the survivors of the female population of age 3 at the present time, and similarly for the projection of ages 1 through 3. The female population less than 1 year old consists of the survivors of the female births during the year. Figure 2-2 illustrates this projection.

Summary Measurements

It is frequently convenient to have one number that summarizes a set of age-specific mortality and fertility rates. Commonly used measures are listed below.

Life Expectancy at Birth. The life expectancy at birth is the most commonly used summary measurement of age-specific mortality. It represents the average age of death of newborns following a given age-specific mortality schedule.

Reproduction Rates (total fertility rate, gross reproduction rate, and net reproduction rate). One useful measure of fertility behavior is the *total fertility rate (TFR)*. The total fertility rate is the average number of children that a cohort of women would bear were each woman to complete her child-bearing years following a given age-specific fertility schedule.

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* Note that these rates are different than age-specific death rates, which give the annual number of deaths per 1000 of the mid-year population of a given age.

† This definition differs somewhat from the one commonly given to the term "infant mortality rate," ie, the probability of dying during the first year of life. The distinction between the definitions lies in the difference between (a) the proportion of babies born during the calendar year (including births on the last day of the year) that do not survive through the last day of the year, and (b) the proportion of babies born the first day of the calendar year that do not survive through the last day of the year.

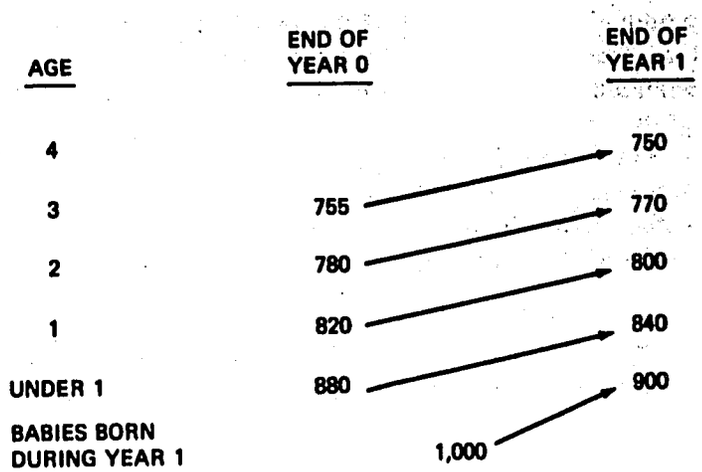

Figure 2-2. A simple age-specific projection.

Another measure of reproductive behavior is the *gross reproduction rate (GRR)*. The gross reproduction rate is similar to the total fertility rate, except that only female births are considered. The gross reproduction rate is found by multiplying the total fertility rate by the ratio of female to total births; that is,

$$GRR = w \cdot TFR$$

where w is the ratio of female to total births. It is assumed this ratio does not vary with the age of the mother.

Because of female mortality, more than one female needs to be born to the average woman for the population to just replace itself. The *net reproduction rate (NRR)* is a measure of fertility adjusted for female mortality. Specifically, the net reproduction rate is the expected number of daughters per newborn female, subject to a stated set of age-specific fertility and mortality rates.

Intrinsic Growth Rates and Stable Populations. One of the most famous and useful discoveries in demography is that if age-specific mortality and fertility rates remain constant for a sufficiently long time period, the population also approaches a constant age distribution. When the age distribution stabilizes, the constant rate at which it is growing is called its *intrinsic growth rate.* Thus, a stable population is generated by the continuation of fixed schedules of fertility and mortality. It is characterized by an unchanged relative age distribution and a constant annual rate of increase.

For example, in 1963 the estimated gross reproduction rate of Japan was 0.965. Life expectancy at birth was 67 for males and 72 for females. The crude birth rate was 17 and the crude death rate 7, resulting in an annual rate of population growth of 1 percent. The population under the age

of 15 accounted for 28 percent of the total population. However, if the age- and sex-specific fertility and mortality rates of Japan remained constant at the estimated 1963 values, the crude birth rate would eventually decrease to 13 and the crude death rate would increase to 16, resulting in an eventual annual growth rate of minus 0.3 percent. That growth rate is the intrinsic growth rate implied by the 1963 fertility and mortality conditions. Given these constant demographic conditions, the proportion of the population under the age of 15 would eventually attain a constant value of 19 percent.

A net reproduction rate of 1 implies an intrinsic growth rate of zero. Because of mortality, a net reproduction rate of 1 always requires a total fertility rate somewhat in excess of 2 and a gross reproduction rate in excess of 1.

The demographic properties of stable populations make them extremely useful in empirical work with incomplete data. Many volumes have been devoted to the useful research tools that have evolved out of stable population theory.* Some of these tools are introduced in Chapter 3.

Instead of using 1-year age cohorts, as in the foregoing example, it is easier and nearly as accurate to make projections using 5-year cohorts. The methodology is basically the same except that 5-year survival rates are used instead of 1-year rates.

Projecting 5-Year Births

The number of births during a 5-year interval is calculated by multiplying age-specific birth rates by the corresponding female populations. A definition of the annual age-specific birth rate of a given group of women has already been given. When fertility is assumed constant, it is common to estimate rates for a 5-year interval by multiplying annual birth rates by 5. Births during a 5-year interval are then projected by multiplying the average number of females in the given age cohort by the resulting birth rate for that cohort.

Survivors of 5-Year Births

The number of births during a 5-year interval surviving to become age group 0-4 by the end of the interval is the product of the projected births during the interval and an infant and child survival rate, ie, the proportion of births during a 5-year interval expected to survive to the end of the interval.

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* See especially Department of Economic and Social Affairs, United Nations Manuals on Methods of Estimating Population, Manual IV, *Methods of Estimating Basic Demographic Measures from Incomplete Data*, Population Studies No. 42, New York, 1967, and Ansley J. Coale and Paul Demeny, *Regional Model Life Tables and Stable Populations*, Princeton University Press, Princeton, New Jersey, 1966.

Exercise 2-1

1.@ Project to the year 2000 a population growing 1 percent, 2 percent, and 3 percent annually, beginning with a population of 1.0 million in 1970 (see the compound interest tables in the Workbook).

2.@ Graph the results of Exercise 2-1.

Discussion: What underlying demographic conditions are required to make this a valid projection procedure?

3. Project 1 year hence the female population given below, ages 5 and younger.

ANSWER:

Age at Last Birthday	Present Female Population		Age-Specific Mortality Rate[a]	Deaths During Year	Population After 1 Year
5					
4	600	X	0.005		
3	650	X	0.008		
2	680	X	0.015		
1	680	X	0.025		
Under 1	780	X	0.050		
Births during year	850	X	0.080		

Note:
[a]The infant mortality rate used here gives the proportion of female births born during the year that die before the end of the year.

4. Project the female populations given below 5 years hence.

Part A: Using death rates. Part B: Using survival rates.

ANSWER: Part A

Age at Last Birthday	Present Female Population	Age-Specific Mortality Rates[a]	Deaths During 5-Year Interval	Population In 5 Years
5 through 9				
Under age 5	740	0.050		
Births during 5 years	1,140	0.150		

Note:
[a]The mortality rates used here give the proportion of the 5-year cohort at the beginning of the 5-year interval that die before the end of 5 years.

ANSWER: Part B

Age at Last Birthday	Present Female Population	Age-Specific Survival Rates[a]	Population In 5 Years
5 through 9			
Under age 5	740	0.950	
Births during 5 years	1,140	0.850	

Note:
[a]The survival rate is 1 minus the 5-year mortality rate.

5. Calculate births during a 5-year interval.

ANSWER

Age at Last Birthday	Female Population			Midpoint Age-Specific Fertility Rate[a]	Births During 5 Years
	Beginning	Ending	Average		
15 through 19	510	590	550	0.10	
20 through 24	440	500	470	0.30	
25 through 29	375	425	400	0.30	
30 through 34	300	340	320	0.25	
35 through 39	270	290	280	0.20	
40 through 44	230	250	240	0.10	
45 through 49	190	210	200	0.02	
TOTAL				1.27	2,400

Note:
[a]Recall that the age-specific fertility rate gives the probability of a woman in the appropriate cohort giving birth during a 1-year interval. With changing fertility, the *average* or mid-point rates for the 5-year interval are used.

6. Calculate the total number of female births if the ratio of male to to female births is 1.05.
7. Calculate the Total Fertility Rate for this group of women.
8. Calculate the Gross Reproduction Rate for this group of women.

DESCRIPTION OF THE POPULATION PROJECTION MODEL

Following is a brief description of the population projection model, based on the discussion of this chapter, that is used in the computer exercises throughout the remainder of the text.

1. Age cohort "i" includes the population ages 5(i−1) through 5i−1. That is, cohort 1 includes ages 0 through 4, cohort 2 includes ages 5 through 9, etc, up to cohort 15 (ages 70 through 74). Cohort 16 includes all ages 75 and older. For cohorts 2 through 15, the number of males in age cohort i is $POP_{m,i}$ and the number of females is $POP_{f,i}$. The size of $POP_{m,i}$ or $POP_{f,i}$ in the year t is the surviving fraction, $s_{m,i}$ or $s_{f,i}$, times the population in the age cohort "i−1" 5 years earlier. Algebraically,

$$POP_{m,i,t} = s_{m,i-1} \cdot POP_{m,i-1,t-5} \quad (i=2,\ldots,15)$$

$$POP_{f,i,t} = s_{f,i-1} \cdot POP_{f,i-1,t-5} \quad (i=2,\ldots,15) \quad .$$

2. The number of males or females in age cohort 16 (ages 75 and older) in year t is equal to the surviving members of the male or female cohorts 15 (ages 70 through 74) and 16 that were present 5 years earlier.

$$POP_{m,16,t} = s_{m,15} \cdot POP_{m,15,t-5} + s_{m,16} \cdot POP_{m,16,t-5}$$

$$POP_{f,16,t} = s_{f,15} \cdot POP_{f,15,t-5} + s_{f,16} \cdot POP_{f,16,t-5} \quad .$$

3. $BIRTH_t$ is the total number of births over a 5-year interval. The number of births in cohort i during the 5-year interval ending in year t is equal to the product of (a) the age-specific birth rate at the midpoint of the interval, b_i, (b) the average female population in the cohort during the interval, and (c) the number 5 (since the birth rates used are annual rates and the calculation is for births over a 5-year interval). $BIRTH_t$, the total number of births, is the sum of the births in cohorts 4 through 10 (ages 15 through 49). Female births, $BIRTH_{f,t}$, are some fraction, w, of total births. Algebraically,

$$BIRTH_t = 5\sum_{i=4}^{10} b_i' \cdot \left(\frac{POP_{f,i,t} + POP_{f,i,t-5}}{2}\right)$$

$$BIRTH_{f,t} = w \cdot BIRTH_t$$

$$BIRTH_{m,t} = BIRTH_t - BIRTH_{f,t}$$

4. The male or female population in the first cohort (ages 0 through 4) represents the surviving population from the births during the preceding 5 years, ie, it is the product of the male or female births ($BIRTH_{m,t}$ or $BIRTH_{f,t}$) and the corresponding infant-child survival rate, $s_{m,0}$ or $s_{f,0}$.

$$POP_{m,1,t} = s_{m,0} \cdot BIRTH_{m,t}$$

$$POP_{f,1,t} = s_{f,0} \cdot BIRTH_{f,t}$$

COMPUTER EXERCISES ON POPULATION PROJECTIONS

Exercise C2-1*

An initial high-fertility, high-mortality population is projected from 1970 to 2020 under constant fertility and mortality conditions. The resulting projection should be used as a basis for answering the following questions. A summary of the basic assumptions used is given as a part of the projection.

1. What does the population profile in 2000 have in common with the profile in 1970?
2. What changes in age- and sex-specific parameters appear to have occurred from 1910 to 1970? (1910 not shown)
3. What changes in age- and sex-specific fertility and mortality appear to have occurred over the course of the projection?
4. Sketch the shape of the population pyramid as you think it would appear if the same projection were extended for an additional 30 years.
5. Using the compound interest tables given in the Workbook, calculate the size of the total population in 2020 following the same trends evident in the computer printout.

Total Population 2020 = _____

Exercise C2-2

The second illustrative computer projection, Exercise C2-2, uses identical assumptions to the first except that infant and child mortality rates are cut in half. A summary of the basic assumptions used is given as a part of the projections.

1. Draw a horizontal line through each population pyramid between those cohorts affected by the change and those not affected.
2.@ Circle the fertile female population in each pyramid. What happens to the proportion of the population represented by females in the reproductive ages during the projection? Draw a graph to illustrate.

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* All computer exercises are designated with the prefix "C" to distinguish them from other exercises throughout the text.

3.@ Plot the crude birth rate and gross reproduction rate. Given that only mortality changed, why does the crude birth rate first fall and later rise?

4.@ Plot the crude death rate and the life expectancy. Why does the former fluctuate more than the latter?

5.@ Plot the growth rates of the population for Exercises C2-1 and C2-2. What was the effect on the population growth rate of cutting infant and child mortality?

Exercise C2-3

The third illustrative computer projection uses identical assumptions to the first except that fertility is cut in half. Repeat the questions of Exercises C2-2 using the projection results from Exercise C2-3.

Exercise C2-4

Introduction to Operating the Computer. This exercise and the ones to follow require you to design your own projections with the computer. Precise instructions for doing so on a particular computer system are provided in a separate handout. The computer exercises are arranged in sequence both in terms of complexity and in terms of the control that the user is given over the outcome of the projections. As the output becomes more difficult to interpret, more time will have to be spent away from the terminal analyzing each run. The analysis of projection results will be easier if an effort is made to try to anticipate results before a run. This discipline will also tend to make the runs more meaningful and the analysis more focused and efficient.

Another procedure that you are urged to follow when first getting acquainted with the computer is to change only one variable at a time for each run, so as to always maintain a point of reference. Only in this way can dynamic interactions be accurately deciphered.

The basic data used for this exercise are the same as those used for Exercise C2-1. The options available for changing parameter values or other data inputs are listed on a separate handout or on the computer printout. The length of the projections and the years for which output will be displayed

can be selected as explained on the computer printout. Several experiments and questions are suggested below.

1. Make a projection that produces a permanent fall in the crude birth rate without changing the fertility or the infant survival rates.
2. Design and carry out an experiment to determine the effect on the growth rate of increasing the initial proportion of the fertile-age population at the expense of the youth population.
3. Generate a projection that increases the future proportion of population ages 0-14 without changing the initial age distribution.

MOMENTUM

A return to the discussion of the momentum of population growth is appropriate at this point, both because the phenomenon should be more understandable after the reader has mastered the demographic tools presented so far and because the concept of momentum summarizes many of the age composition effects.

Population momentum is present whenever the percentage change in the crude birth rate is less than the percentage change in the gross reproduction rate. This generally occurs, because the proportion of the population in the fertile ages tends to increase with falling fertility and to decrease with rising fertility.

Recall that the crude birth rate can be decomposed into the product of two ratios, (1) the ratio of births to fertile-age population and (2) the ratio of fertile-age population to the total population.

$$\text{CBR} = \frac{\text{births}}{\text{total population}}$$

$$= \frac{\text{births}}{\text{fertile-age population}} \cdot \frac{\text{fertile-age population}}{\text{total population}}$$

Decreasing fertility decreases the first ratio by approximately the same proportion,* but it increases the second ratio. The combined effect is a less than proportional fall in the crude birth rate.

The growth rate of the fertile-age population is determined primarily by the fertility and mortality conditions of the preceding two or three decades, and is independent of current fertility conditions. If fertility rates have been high and mortality rates low, a high rate of growth for fertile-age females will be assured for the next 20 years. A decrease in fertility will reduce the rate of growth of the younger population, thereby increasing the proportion of the population in the fertile ages. Similarly, if fertility has been low and then increases, the proportion of the population in the fertile ages will decrease.

* Changing age composition also affects this ratio but generally to a smaller extent.

Exercises

The following exercises, which feature the option to introduce time trends in fertility and mortality, are designed to explore in greater detail the concept of momentum. Basic demographic data are provided separately for several countries, each of which represents a different stage in the transition from high to low fertility and mortality. The data include initial population by age and sex, age-specific fertility rates, and age- and sex-specific survival rates. Summary measurements of fertility and mortality are included for each country on the computer printout.

Exercise C2-5

This exercise makes a projection of a population to the year 2000 assuming that there is a substantial decline in both fertility and mortality from the high fertility and mortality conditions of one country to the low fertility and mortality of conditions of another.

1. Compare the crude birth and death rates for the projected population in the year 2000 with the crude birth and death rates of the low mortality and fertility country in 1970. What accounts for the differences you observe?

2.@ Plot the projected crude birth rates, crude death rates, and gross reproduction rates as percentages of their 1970 values. What accounts for the differences you observe? If the crude birth rate had fallen as rapidly as the gross reproduction rate and the projected crude death rate had remained unchanged,* how much would the projected growth rate have changed during the projection?

   The preceding projection involves a mixture of changing both fertility and mortality. Do a second projection, assuming that fertility conditions remain constant and that there is a transition from high-mortality to low-mortality conditions. Repeat Questions 1 and 2.

Suggested Additional Variations with Exercise C2-5

Initial populations and birth and death assumptions may be selected from any of the different country data sets used in the preceding projections. Any combination of assumptions is permissible. Momentum can best be observed by starting with the initial demographic parameters of a high-fertility country and permitting fertility to decline to the level of a low-fertility country over a 30- or 40-year period. Compute the percent

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* Be aware, however, that the crude death rate would normally change as well so that the assumption of constancy will bias the results. (In which direction do you think the bia will be?)

increase in population that occurs in the transition. Run a second projection, again using the high-fertility country's fertility and survival schedules with the same time trend in fertility, but this time beginning with the low-fertility country's age distribution.

Again compute the percentage increase in the transition period. The additional relative increase in population observable in the first run is due to the effect of age composition, ie, to momentum.

Experiments and Questions

1. Set up the above experiment on the computer and fill in the blanks from the results.
   a. Country from which initial population is drawn: _____
   b. Country from which final fertility rates are taken: _____
   c. Percent increase in population, run 1: _____
   d. Percent increase in population, run 2: _____
2. Find the country, from among the sets available, that has the age composition with the most potential for maintaining:
   a. High rates of growth in the face of a fertility decline.
   b. Low rates of growth in the face of a fertility increase.

ZERO POPULATION GROWTH (ZPG)

One demographic target that is often mentioned is "zero population growth" (ZPG). For any given country, two questions arise: how long will it take to reach ZPG and how large the ultimate stationary population will be. The following experiments are designed to address these two questions. The time necessary to reach ZPG is determined by the rates of decline of fertility and mortality and by the initial age and sex composition of the population.

For present purposes, the problem of mortality transition is treated by arbitrarily fixing a target female life expectancy at birth of 75 years. It is also assumed that all countries will eventually have the same age pattern of fertility.* These two assumptions enable us to calculate a target fertility schedule that combines with the assumed survival schedule to yield a net reproduction rate of 1. As mentioned earlier, a population with a net reproduction rate of 1 has an intrinsic growth rate of zero. Once the age composition stops changing, the number of births will just equal the number of deaths, ie, the population stops growing.

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* The pattern selected comes from A.J. Coale and P. Demeny, *Regional Model Life Tables and Stable Populations*, Princeton University Press, Princeton, N.J., 1966. The mean age of motherhood is assumed to be 29.

Exercise C2-6

Select an initial age and sex composition and initial fertility and survival schedules from the list given in Exercise C2-5. Specify the transition periods during which the life expectancy reaches 75 years and the gross reproduction rate reaches 1.115 (the rate that is consistent with an NRR of 1). To facilitate the interpretation of results and the fixing of initial conditions, the following data are given for four countries that have experienced rapid fertility declines in recent history.

Country	GRR (1960)	GRR (1970)	Year in Which The 1960 to 1970 Rate of Decline will Result in a GRR of 1.115
Costa Rica	3.58	2.26	1985
Chile	2.30	1.60	1980
Taiwan	2.79	1.94	1986
Korea	3.02	1.92	1982

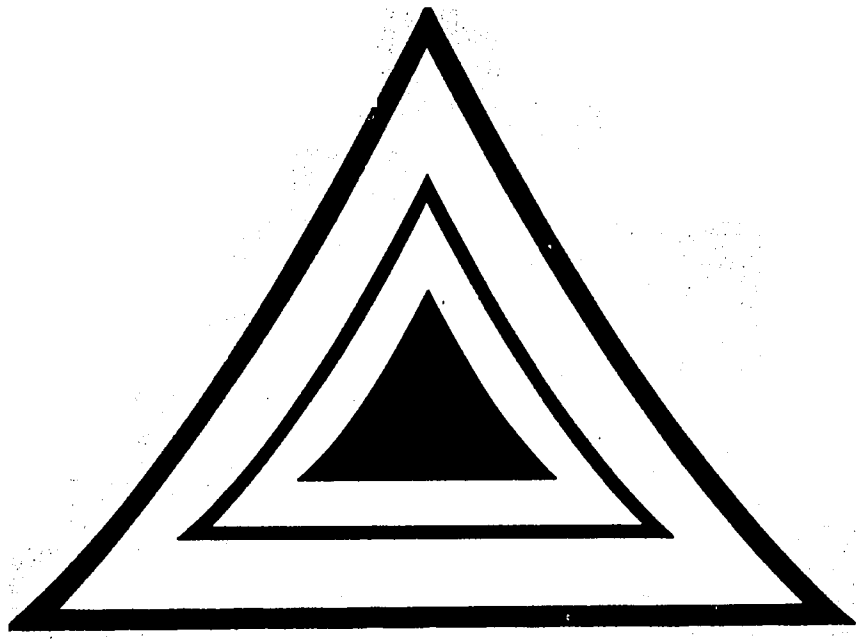
Run a series of projections with the available data. For each experiment, report the following:

1. Time necessary to reach ZPG after reaching the target GRR. For practical purposes, ZPG is considered to have been attained when the growth rate of the population reaches ± 0.1 percent.
2. Percentage increase in population after the target GRR is reached.

Discussion: What is the significance of the phenomena you have studied in this set of exercises for population planning? For example, what is a plausible minimum size of the future population of each country you used in your experiments?

CHAPTER 3

STABLE POPULATION TECHNIQUES



STABLE POPULATION TECHNIQUES

(Note: The materials discussed in this chapter are substantially more technical than the other demographic concepts presented in this text. Students who are being introduced to demography for the first time are urged to pass over this section on the first reading.)

INTRODUCTION

The availability and quality of demographic data vary widely from country to country. At one end of the scale are rough guesses of the total population and how rapidly it is growing. On the other hand, there may be census data for one or more years on the age and sex distribution of the population, possibly supplemented by survey and registration data on conditions of mortality and fertility. If these data are in the raw state, some further refinement is generally possible using relatively simple techniques.

A variety of techniques can be used to obtain more and better information from the limited amounts of data often available. Many of these techniques are based on the theory of stable populations, which was discussed briefly in Chapter 2. Seemingly small amounts of data can be combined with stable population materials and techniques to obtain a set of data suitable for demographic projections of the type used in this text. This chapter is a brief introduction to some of these stable population techniques.*

CHARACTERISTICS OF STABLE POPULATIONS

Recall that the term "stable population" refers to the population that results when fertility and mortality are held constant for a sufficiently long period of time for the age distribution and the growth rate to become constant. In the strict sense, therefore, stable population analysis is applicable

* The full range of techniques available for the refinement of demographic data and development of population projections constitutes a major field that lies far beyond the scope of the present discussion. Readers interested in pursuing the subject further are referred to A. Coale and P. Demeny, *Regional Model Life Tables and Stable Populations*, Princeton University Press, Princeton, 1966, or United Nations, *Methods of Estimating Basic Demographic Measures from Incomplete Data*, Population Studies, No. 42, New York, 1967.

only when certain conditions are satisfied. In the words of one widely used United Nations population study,

> The question of when estimates can be based on stable population analysis is easily answered in principle: whenever fertility has been subject to no more than low-amplitude and short-duration variations during the previous five or six decades, and mortality has changed only slightly and gradually during the past generation.*

With modifications, the techniques may also be used to deal with so-called "quasi-stable" populations, which are characterized by relatively constant fertility conditions and declining death rates.†

For every population with a constant age distribution and a constant growth rate, there is a unique set of age-specific survival rates or life table. Conversely, for every set of age-specific survival rates and constant growth rate, there exists a stable population with a unique age distribution. Stable population analysis utilizes these relationships and others directly derivable from them.

REGIONAL MODEL LIFE TABLES AND STABLE POPULATIONS

The source of the most extensive materials for stable population analysis is the Coale and Demeny volume referred to in the footnote on page 3-1. It presents four families of model male and female life tables and stable population age distributions, identified by the designations East, North, South, and West. These "regional" tables are characterized briefly as follows:

> *East.* The East model tables summarize life tables from Austria, Germany, Czechoslovakia, North and Central Italy, Hungary, and Poland. They are characterized by high mortality in infancy and increasingly high rates over age 50.
>
> *North.* These summarize tables from Norway, Iceland, and Sweden until 1920. They are characterized by low infant mortality rates and rates that are lower by an increasing margin for ages beyond 45 to 50.
>
> *South.* These summarize tables from Spain, Portugal, and Southern Italy. They are characterized by high mortality under age 5, low mortality from about age 40 to age 60, and high mortality over age 65.

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* United Nations, *op cit*, p 12.

† *Ibid*, pp 25-29.

West. The West tables, which represent the typical age pattern of mortality evidenced by the 326 life tables used, reflect the life tables of Australia, Belguim, Canada, Denmark, England and Wales, Estonia, Finland, France, Ireland, Israel, Japan, Latvia, Luxemburg, Netherlands, New Zealand, Scotland, Sweden from 1931, Taiwan, the Unior of South Africa white population, and the United States.

The most available and commonly used tables are those for the West region. Many parts of the world, however, might be better represented by tables of one of the other three regions.

AN ILLUSTRATIVE APPLICATION OF STABLE POPULATION TECHNIQUES

The remainder of Chapter 3 discusses an illustrative example of the estimation of the age distribution, age-specific birth rates, and age- and sex-specific survival rates of a population by applying stable population techniques to an incomplete set of demographic data. Although it is somewhat specialized, as is discussed at the end of the chapter, the example illustrates how a full set of demographic data can be constructed from modest amount of raw material.

Available Data

Assume that the data in Table 3-1 are available for a country named Developa. These data include census estimates of the female population by age, the total male and female populations, the ratio of male to female birth and the estimated growth rate of the population.

Only the female population is given by age. Although the number of females in each age group is misreported, the distortion in our hypothetical country is much worse for males. We therefore will use the female age com position and stable population tables to obtain an age distribution for the males.

Also, the conditions in Developa that determine the age pattern of fertility are similar to those in a neighboring country with the following age-specific birth rates:

Age	Birth Rate (per 1000)	Age	Birth Rate (per 1000)
15-19	85	35-39	140
20-24	227	40-44	62
25-29	234	45-49	15
30-34	190		

Table 3-1. Hypothetical demographic data.

Female Population by Age			
Age	Female Population (thousands)	Age	Female Population (thousands)
0-4	360	35-39	82
5-9	314	40-44	90
10-14	202	45-49	76
15-19	194	50-54	70
20-24	202	55-59	40
25-29	134	60-64	46
30-34	146	over 64	44

Population Totals (thousands)		
Male	Female	Total
1,985	2,000	3,985

Ratio of male to female births:	1.05
Annual growth rate of population:	3.0 percent

Finally, evidence exists that conditions of fertility and mortality have been constant long enough to approximate the requirements for stable population analysis. The conclusion is based on the relative constancy of the age distribution reported by the censuses of the last 20 years, in addition to the opinions of medical authorities.

Estimation of a Complete Data Set

The data needed for the demographic projections can be derived using these materials and readily available stable population materials. The data required for a projection are: (1) the initial population by age and sex, (2) an initial set of survival rates by age and sex, (3) an initial set of age-specific birth rates, (4) the ratio of male to female births, and (5) assumptions that specify how the survival rates and birth rates will change during the projection. The fourth item is given to us in the basic data, and the fifth is based primarily on assumptions. The example below demonstrates how the first three types can be obtained.

Mortality Level. First, the female age distribution and the annual rate of growth are used to find a West life table with the appropriate level of mortality. This is done by (1) computing a cumulative age distribution for

the female population, (2) determining which mortality level would, with a growth rate of 3.0 percent, result in the given proportion of the female population up to each specified age, and (3) taking the median of the mortality levels thus computed.

The first step requires finding the proportion of the female population in each 5-year age cohort, and then for every fifth year adding the cohorts up to the specified age to find the portion of the female population under that age. The results of these calculations are given in Table 3-2.

Table 3-2. Deriving cumulative age distributions.

Age Cohort X	Percent of Population in Age Cohort X	Age Z	Percent of Population Under Age Z
0-4	18.0	5	18.0
5-9	15.7	10	33.7
10-14	10.1	15	43.8
15-19	9.7	20	53.5
20-24	10.1	25	63.6
25-29	6.7	30	70.3
30-34	7.3	35	77.6
35-39	4.1	40	81.7
40-44	4.5	45	86.2
45-49	3.8	50	90.0
50-54	3.5	55	93.5
55-59	2.0	60	95.5
60-64	2.3	65	97.8
over 64	2.2		

The second step is to find the mortality level for all ages up to each specified age. This will generally require linear interpolation. For example, with the 3.0 percent growth rate, the West female model life tables with mortality levels of 17 and 19 result in 53.65 percent and 52.62 percent, respectively, of the population below age 20. Our hypothetical population has 53.5 percent of the reported female population below the age of 20. This is 15 percent* of the distance from 53.65 to 52.62. The mortality level obtained by linear interpolation is 17 plus 0.15 times the distance between 17 and 19 (17 plus 0.15 times 2), or 17.3.

* That is, 100 times 0.15 ÷ 1.03.

This calculation is repeated for each of the first nine cohorts. The results of the second step are presented in Table 3-3.

Table 3-3. Mortality level calculation results.

Age	Mortality Level	Age	Mortality Level
5	13.5	30	16.1
10	11.5	35	14.1
15	16.1	40	16.2
20	17.3	45	15.8
25	14.9		

The median mortality level is 15.8. The model female age distribution associated with this mortality level, obtained by interpolating between the age distributions for mortality levels 15 and 17, is contrasted with the reported age distribution of Developa in Figure 3-1.

Crude Birth Rate. This mortality level, the age distribution of the associated stable population, and the growth rate of 3.0 percent imply a death rate of the female population of 11.5 per thousand and a birth rate of 41.5 per thousand. The expectation of life at birth, also obtained by interpolating between mortality levels 15 and 17, is 57.0 years.

These parameters plus the ratio of male to female births and the ratio of males to females in the population* are then used to compute estimates of the male parameters. We first compute the male birth rate, using the formula†

$$\text{male birth rate} = \frac{\text{(female birth rate) (sex ratio at birth)}}{\text{(sex ratio of population)}}$$

$$= \frac{(0.0415)\ (1.05)}{(1{,}985/2{,}000)}$$

$$= 0.0439, \text{ or } 43.9 \text{ per thousand.}$$

* Caution: underreporting of males is an important cause of faulty age distributions. The procedure used here implies that this is not a problem in Developa.

† This formula is derived from the identity

$$\frac{\text{male birth rate}}{\text{female birth rate}} = \left(\frac{\text{male births}}{\text{male population}}\right) \Big/ \left(\frac{\text{female births}}{\text{female population}}\right)$$

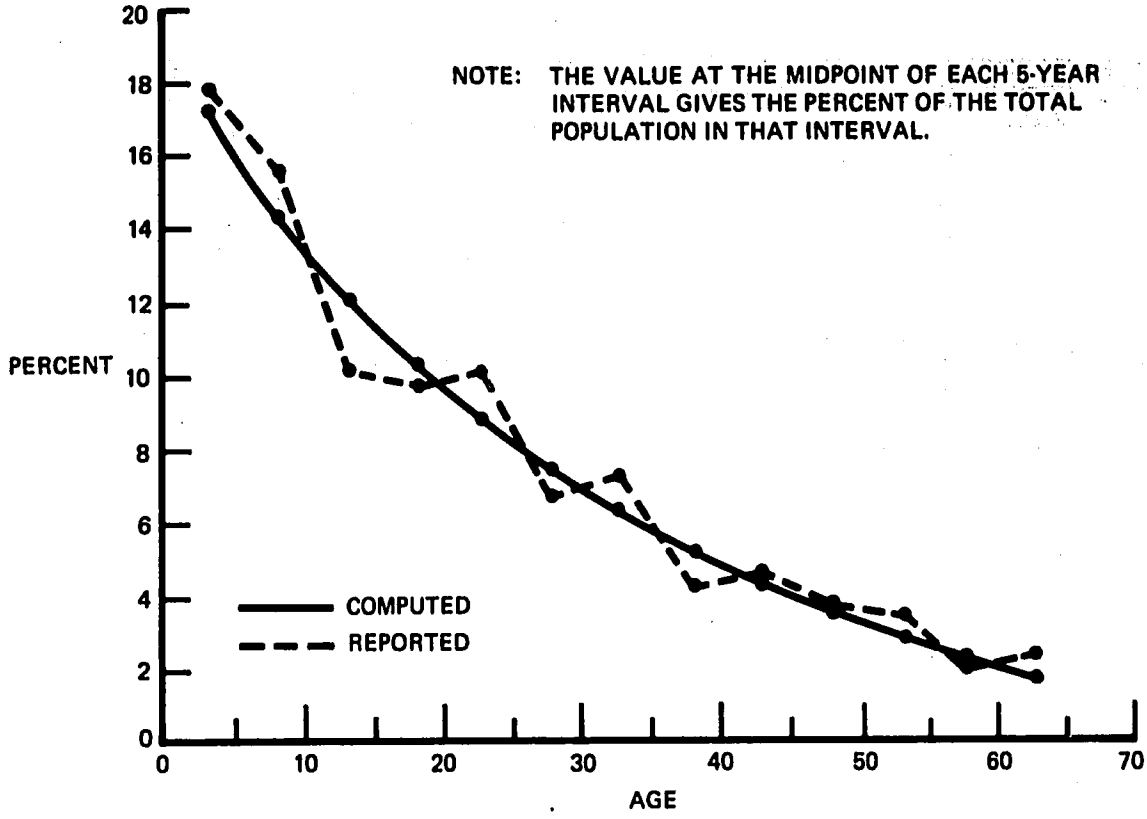


Figure 3-1. Contrast of reported female age distribution and age distribution computed for mortality level 15.8.

By subtracting the growth rate of 3.0 percent, or 30 per thousand, from the male birth rate of 43.9 per thousand, we obtain a male death rate of 13.9 per thousand. The growth rate of 3.0 percent and death rate of 13.9 identify the West male mortality level of 15, with a life expectancy at birth of 51.8 years.

The crude birth rate (for the total population) is obtained as a weighted average of the male and female birth rates as follows:

$$\text{CBR} = \frac{(\text{male pop.})(\text{male birth rate}) + (\text{female pop.})(\text{female birth rate})}{(\text{total population})}$$

$$= \frac{(1{,}985)(0.0439) + (2{,}000)(0.0415)}{(3{,}985)}$$

$$= 0.0427, \text{ or } 42.7 \text{ per thousand.}$$

We now have all of the material necessary to compute the needed demographic data in a straightforward fashion.

Initial Population. The age distributions of the initial male and female populations are taken from the stable populations associated with the growth rate of 3.0 percent and the mortality levels of 15 for males and 15.8 for females. In this instance, the male age distribution can be taken from available tables. The female age distribution must be obtained by linear interpolation of the stable population tables for mortality levels 15 and 17. The interpolation is applied to the cumulative age distribution. Table 3-4 illustrates the process.

The derived cumulative age distribution then is decomposed to obtain the desired age distribution. Table 3-5 shows the derived female age distribution and the male age distribution associated with mortality level 15. The initial male and female populations are then computed by multiplying these age distributions by the total male and female populations.

Table 3-4. Cumulative female age distributions for mortality levels 15, 17, and 15.8.

Age X	Percent of Population Under Age X		
	Mortality Level		
	15	17	15.8
5	17.5	17.0	17.3
10	32.0	31.2	31.7
15	44.3	43.3	43.9
20	54.8	53.6	54.3
25	63.6	62.4	63.1
30	71.0	69.8	70.5
35	77.1	76.1	76.7
40	82.3	81.3	81.9
45	86.6	85.7	86.2
50	90.1	89.3	89.8
55	93.0	92.3	92.7
60	95.3	94.8	95.1
65	97.0	96.7	96.9
70	98.3	98.1	98.2
75	99.2	99.0	99.1

Table 3-5. Male and female population distribution.

Age	Male		Female	
	Percent	Population (thousands)	Percent	Population (thousands)
0-4	17.8	353	17.3	346
5-9	14.7	292	14.4	288
10-14	12.4	246	12.2	244
15-19	10.6	210	10.4	208
20-24	8.9	177	8.8	176
25-29	7.5	149	7.4	148
30-34	6.2	123	6.2	124
35-39	5.2	103	5.2	104
40-44	4.3	85	4.3	86
45-49	3.5	69	3.6	72
50-54	2.8	55	2.9	58
55-59	2.2	44	2.4	48
60-64	1.6	32	1.8	36
65-69	1.1	22	1.3	26
70-74	0.7	14	0.9	18
75+	0.6	12	0.9	18
Total	100.1	1986	100.0	2000

Survival Rates. The initial survival rates are taken from the model life tables associated with mortality levels 15 for males and 15.8 for females. Again, the survival rates for males are taken directly from available tables, but the female survival rates are obtained by interpolation. Linear interpolation is applied to the survival rates* of the model life tables for mortality levels 15 and 17. The computed female survival rates and the male survival rates for level 15 are shown in Table 3-6.

* Labeled P(X) in the Coale and Demeny volume and ${}_5L_{x+5}/{}_5L_x$ in the U.N. volume cited earlier.

Table 3-6. Survival rates.

Age[a]	Female			Male
	Level 15	Level 17	Level 15.8	Level 15
0	0.889	0.917	0.900	0.872
1	0.961	0.974	0.966	0.954
5	0.986	0.990	0.988	0.986
10	0.985	0.990	0.987	0.985
15	0.980	0.986	0.982	0.979
20	0.976	0.982	0.978	0.974
25	0.972	0.980	0.975	0.971
30	0.969	0.976	0.972	0.966
35	0.964	0.972	0.967	0.958
40	0.958	0.966	0.961	0.946
45	0.946	0.955	0.950	0.929
50	0.927	0.938	0.931	0.904
55	0.897	0.910	0.902	0.866
60	0.849	0.865	0.855	0.811
65	0.778	0.797	0.786	0.736
70	0.676	0.697	0.684	0.632
75	0.424	0.443	0.432	0.393

Note:

[a] The rows designated 0, 1, and 75 give the survival rates for "infants," ages 0-4, and over 74, respectively. The other rows give the survival rates for the 5-year cohort beginning with the age given. This follows the age notation commonly used in model life tables.

Birth Rates. The final data needed are the age-specific birth rates. These are obtained with the use of the age-specific birth rates of the neighboring country. Application of these neighboring birth rates to Developa's female population results in 136.8 thousand births. Developa's crude birth rate of 42.7 per thousand and total population of 3,985 thousand imply 170.2 thousand births, which is 1.244 times the number calculated with the neighboring birth rates. Assuming that the age pattern of birth rates for Developa and the neighboring country are identical, the estimated age-specific birth rates for Developa are obtained by multiplying each of the neighboring birth rates by the adjustment factor of 1.244. The resulting birth rates are given in Table 3-7.

Table 3-7. Estimating age-specific birth rates.

Age	Neighboring Country Birth Rates (per thousand)	Estimated Developa Birth Rates (per thousand) (Col. 1) X 1.244[a]
15-19	85	106
20-24	227	282
25-29	234	291
30-34	190	236
35-39	140	174
40-44	62	77
45-49	15	19

Note:

[a]Births calculated using neighboring age-specific birth rates (A): 136.8 thousand

Births in Developa consistent with crude birth rate of 42.7 per thousand (B): 170.2 thousand

Adjustment factor (B/A): 1.244

Specialized Nature of the Example

The preceding example, while illustrative of the nature of stable population techniques, is specialized in two important aspects. First, it assumed that the population was very nearly stable in a literal sense. However, unstable populations are the rule, not the exception. Second, the specific set of demographic data available for Developa depicted only one of many data situations the reader might confront.

The assumption that the population is stable can always be made *as an approximation.* However, systematic divergences from the characteristics of a truly stable population commonly exist. If a divergence is large enough, it can seriously affect the results of the projections.

Almost universally, mortality rates have been declining (ie, survival rates increasing) during recent decades. A population with gradually declining mortality and relatively constant fertility, known as a quasi-stable population, is what one would expect to find in most of the less developed countries. Stable population techniques can be adapted to quasi-stable conditions.*

* United Nations, *op cit,* pp 25-29. This document discusses demographic projection techniques applicable to several different data situations.

More troublesome, but less frequent, are populations for which both mortality rates and fertility rates have been falling. Finally, one must constantly be on the alert for extraordinary events, such as wars, that may seriously affect the age composition and growth of a population. Some corrections can be made for these factors, but they generally require significantly greater sophistication in demographic techniques.

Exercise C3-1

This exercise uses two projections, the first assuming constant fertility and a gradual decline in mortality to a pre-specified level at the end of 30 years, and the second projection assuming that both fertility and mortality decline to pre-specified levels.

The first projection gives us a quasi-stable population. Suppose we did not have this projection but knew only that Developa had a life expectancy at birth for females of 70 years and the growth rate of the population (ie, the growth rate from the first projection).

Questions

1. Find the intrinsic growth rate from the Workbook table for this exercise that most closely corresponds to the population growth rate in the final year of the first projection. Compare the corresponding stable age distribution with the quasi-stable distribution produced by the projection.
2. What is the difference between the projected CBR in the final year and the one corresponding to the stable population?
3. What is the difference between the projected CDR in the final year and the one corresponding to the stable population?
4. Repeat Questions 1 through 3, comparing the appropriate stable population parameters from the table with the population parameters generated in the second projection.
5. For which projection do the stable population parameters provide the closest approximation?
6. Do the errors introduced by using stable population parameters to represent unstable and quasi-stable populations appear to be significant?

EDUCATION AND MANPOWER

INTRODUCTION TO PART II

Part II deals with the relationships between demographic change and demographically sensitive demands for goods and services. Examples of such demands are for health care, housing, education, jobs, recreation, and retirement benefits. In this section, a framework of analysis is presented that can be used to investigate a broad spectrum of these demographically sensitive demands. Education and employment are given specific attention.

It is not easy to predict future requirements for housing, health care, social security benefits, and other basic social services even though the relevant variables that affect demand may be well known. On the one hand, the interplay of demographic forces produces changes in the growth rate and the age and sex distribution of the population, with corresponding changes in the appropriate menu of social services. On the other hand, the definition of requirements tends to change. Expectations rise with progress and today's luxuries become tomorrow's necessities.

The more complex a planning problem becomes, the more important it is to examine the more predictable changes. Despite the associated uncertainties, demographic variables lie at the relatively predictable end of the spectrum, so that demographic analysis generally provides a logical starting point for social planning. For example, the size of the school-age population in the future will be a major determinant of the growth of required inputs to the educational system such as teachers, classrooms, educational aids, and books.

Estimating the present and future size of the school-age population is a basic step for educational planning. The future size of this population, both in absolute numbers and as a percentage of the total population, is very sensitive to changes in fertility and infant mortality. For planning purposes, it is essential to anticipate fluctuations in the school-age population in order to match the capacity of the school system with the anticipated demands to be placed upon it.

On the supply side, this task is complicated by the variable lead times required to provide additional educational inputs such as classrooms and teachers. For example, it may take 2 years to construct a new school after

the decision to build has been made, and 4 years to train a new teacher. The fact that schools last a long time adds another complicating element. Consider the effect of a fall in the number of births on the demand for school capacity. Is it prudent to build a 20-year facility to meet current demands if it will be used for 5 or 10 years and remain idle for the rest of its useful life?

Failure to plan for demographic change has resulted in unemployed teachers and excess classrooms in the United States during the present decade. In other countries a similar failure has resulted in a chronic shortage of teachers. Because of the strong relationship between educational demand and demographic change and the lengthy process of increasing the supply of teachers and buildings, educational planners should pay close attention to anticipated changes in the demographic variables.

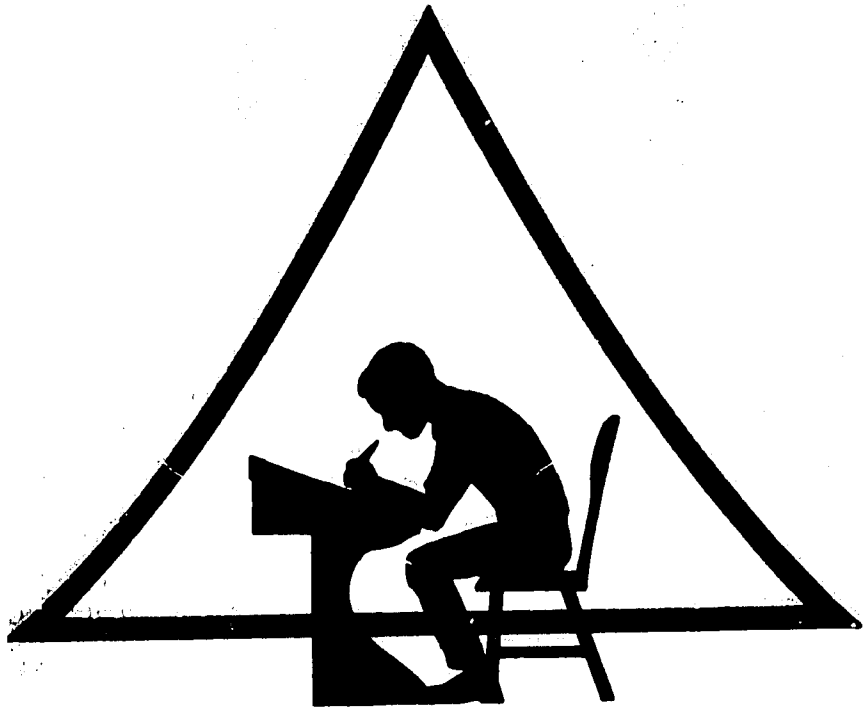
Demographic changes also affect the labor force and its growth. For instance, a reduction in mortality has the effect of increasing the size of the labor force and thus the number of jobs required for full employment. The high rates of growth of population and labor force now experienced by the developing countries are mainly due to the rapid declines in mortality in recent decades. This rapid growth of the labor force has aggravated the problems of unemployment and underemployment in those countries. Manpower planners need labor force projections to formulate plans for dealing with the anticipated growth of the population seeking employment. Plausible targets for reducing the unemployment rate can then be set that take into account the anticipated additions to the labor force and the additional employment that could be generated.

Chapter 4 presents an educational model for projecting the contribution of demographic change to the configuration of an educational system. The model projects the possible enrollments and costs that result from various demographic developments and program objectives, eg, desired enrollment and advancement rates.

Chapter 5 deals with the impact of changing fertility or mortality on future labor force growth and its implications for attaining and maintaining full employment.

CHAPTER 4

THE IMPACT OF DEMOGRAPHIC CHANGE ON THE DEMAND FOR EDUCATION



THE IMPACT OF DEMOGRAPHIC CHANGE ON THE DEMAND FOR EDUCATION

INTRODUCTION

The focus of this chapter is on projecting the impact of different demographic conditions on the resources required (such as teachers and classrooms) to achieve various educational targets. Some consideration is also given to the effects of increasing educational aspirations. The school system may plan to upgrade its programs by reducing the number of children per teacher and per classroom. This adds an increment to the resources required on top of those needed to service growing enrollments. Improvements in the quality of education may also reduce the number of children dropping out during the year, improving the efficiency of the system and at the same time generating an additional demand for school personnel and facilities.

The full complexity of the educational planning process cannot be dealt with in a simple model. We have therefore chosen a model that focuses attention on the effects of demographic variables while permitting limited exploration of the effects of altering non-demographic variables.*

The educational model might be considered a set of accounting procedures that assigns the numbers of age-eligible people, generated by the demographic model, to different places inside and outside the educational system. Thus, a currently enrolled primary student may proceed to one of four categories 5 years from now: he may be enrolled in secondary school, he may still be enrolled in primary school, he may be a dropout, or he may be dead. To simplify the calculations, the model excludes the possibility of remaining in primary school and does not differentiate between dying and dropping out.

The total enrollment is calculated by using a pre-specified target enrollment ratio for the students entering primary school. Enrollments in the later grades depend on how many children proceed to each successive level in the school system. (The enrollment ratio for these older students is then calculated using the total number of people in the appropriate age group projected by the demographic model.) Given the projection of

* The model used in this chapter is a simplified version of a more complete educational projection model developed by TEMPO. See *The TEMPO Educational Projection Model*, Douglas L. Maxwell, July 1974 (GE74TMP-15).

enrollments and the number of students per teacher and classroom, the model calculates the number of teachers and classrooms needed. Teacher and classroom costs are then combined to obtain a total educational budget.

Graduates from some specified level of the school system become eligible to teach in lower grades. They therefore provide potential additions to the teacher corps to meet new demands caused by rising enrollments or a reduction in the number of students per teacher.

PROJECTING STUDENT ENROLLMENTS

The number of students entering the educational system at the primary level, ENRP, is assumed proportional to the population ages 5 through 9, where the enrollment ratio, erp, for each year is pre-specified:*

$$ENRP_t = erp \cdot POP_{2,t} \quad , \tag{1}$$

where $POP_{2,t}$ is the second age cohort (ages 5 through 9).

Having once entered the educational system, students either advance to the secondary level or dropout over the succeeding 5 years. Enrollments in the secondary level, ENRS, in a given year are thus proportional to primary enrollments 5 years earlier, where the advancement ratio, advps, is pre-specified:

$$ENRS_t = advps \cdot ENRP_{t-5} \quad . \tag{2}$$

The projection assumes that secondary enrollment normally occurs during ages 10 through 14. A secondary enrollment ratio, ers, is thus calculated by dividing projected secondary enrollments by the population in the third age cohort, POP_3:

$$ers_t = ENRS_t / POP_{3,t} \quad . \tag{3}$$

Third level, or tertiary, enrollments are calculated in a similar manner. It is assumed that the tertiary enrollments, ENRT, in a given year are proportional to the secondary enrollments 5 years earlier, where the advancement ratio, advst, is pre-specified:

$$ENRT_t = advst \cdot ENRS_{t-5} \quad . \tag{4}$$

The tertiary enrollment ratio, ert, is the ratio of tertiary enrollments to the population in the fourth age cohort, POP_4, ages 15 through 19:

---

* Beginning and ending enrollment ratios are pre-specified as data, and the intermediate values are determined by linear interpolation. Other pre-specified parameters can be changed in a similar manner.

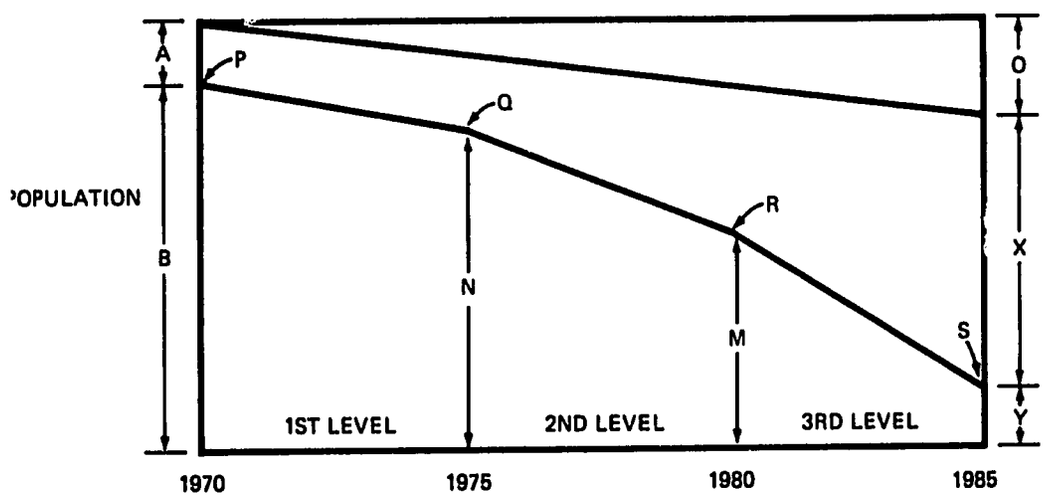
$$ert_t = ENRT_t/POP_{4,t} \quad . \tag{5}$$

Graduates from the tertiary level during a 5-year interval are proportional to tertiary enrollments at the beginning of the interval:

$$GRAD_t = gr \cdot ENRT_{t-5} \quad . \tag{6}$$

Note that the primary enrollment ratio, erp, the two advancement ratios, advps and advst, and the graduation rate, gr, are subject to direct control, while the secondary and tertiary enrollment ratios are outputs of the projection.

Figure 4-1 illustrates the flow of children through the various educational levels. The progress of one cohort, born during the years 1960 through 1964, is traced over the period 1970 to 1985. Mortality reduces the size of the cohort, but the school enrollment shrinks even faster due to dropouts.



A + B	=	Total population of cohort 2 (ages 5 through 9) in 1970
X + Y	=	Total population of cohort 5 (ages 20 through 24) in 1985
B/(A + B)	=	Primary enrollment ratio
A	=	Non-enrolled children in cohort 2
B	=	Enrollments for cohort 2
N	=	Primary graduates that advance to the secondary level
M	=	Secondary graduates that advance to the tertiary level
O	=	Total deaths from 1970 through 1985
X	=	The number of surviving school dropouts
Y	=	Graduates from the tertiary level.

Figure 4-1. Flow of student enrollments.

Review Questions

1. Assume that the primary enrollment ratio is 0.50 and that the advancement rates from primary to secondary levels and secondary to tertiary levels are 0.20 and 0.40, respectively. For each 1,000 children ages 5 through 9 in 1970, how many would be enrolled at the primary level in 1970, secondary level in 1975, and tertiary level in 1980? What information would you need to project the primary and secondary enrollments in 1980?

2. Assume that the survival rates for the second and third age cohorts (ages 5 through 9 and ages 10 through 14, respectively) are 0.95 and 0.98, respectively. Using the results of Question 1, what are the projected enrollment ratios for the secondary level in 1975 and tertiary level in 1980?

Exercise C4-1

For this exercise the computer projects enrollments and teacher requirements for the period 1970 to 2000 using the population projections of Exercise C2-1. The teacher projections will be used in the next exercise, C4-2, and should be ignored for the time being.* Fertility and mortality are assumed constant, as are advancement and enrollment rates. A summary of the important assumptions is given as part of the projection.

Analyze the projection and answer the following questions. It will also be useful to review the projection results obtained in Exercise C2-1 before performing this exercise. Note that if all of the enrollment ratios remain constant throughout the projection, this indicates that the population being projected has a constant age distribution; ie, the population is stable.

1. Using the projections and the compound interest tables provided in the Workbook, calculate the average annual growth rate of the population ages 5 through 9.

2. What is the average annual growth rate of the total population?

3. Are graduates from the secondary and tertiary levels growing at the same rate, faster, or slower than the total population?

---

* If the option is given, be sure to ask the computer to print the TEACHER table.

PROJECTING TEACHER REQUIREMENTS

The number of teachers required for a given level in school in a given year depends on the number of students at that level and the ratio of students to teachers. In the projections, the student-teacher ratio is pre-specified. Algebraically,

$$TEACHERS_t = tsr \cdot ENR_t \quad , \tag{7}$$

where ENR represents the enrollments projected for the appropriate level and tsr is the corresponding ratio of teachers to students, ie, the reciprocal of the student-teacher ratio.

As an indication of the demands on teacher education implied by the projections, it is useful to look at the *change* in teacher requirements from one year to another. The projection therefore gives the demand for "new teachers" required over each 5-year interval,

$$NEWTEACHERS_t = TEACHERS_t - TEACHERS_{t-5} \quad . \tag{8}$$

This calculation underestimates somewhat the demand for new teachers, since it ignores the loss of teachers due to death and retirement. In other words, the projections give the *net* demand for new teachers, not the *total* demand.

In many countries, the demand for teachers is increasing rapidly due to a combination of factors: (1) growth of school-age populations, (2) increasing enrollment ratios, and (3) decreasing student-teacher ratios. The growth of the school-age population is, of course, quite sensitive to changes in fertility. Figure 4-2 illustrates this sensitivity and its impact on teacher requirements. Panel A of Figure 4-2 depicts the growth of primary teacher requirements for Developa under two different fertility assumptions. The first projection assumes that fertility remains constant, while the second assumes that fertility falls by 50 percent during the projection. Both projections assume that the education parameters remain constant. Panel B of Figure 4-2 projects the annual demand for *new* primary teachers. Note that during the declining fertility projection, the demand for new teachers temporarily becomes negative. In other words, with rapidly falling fertility the number of teachers required may also fall.

Such a projected decline may have several implications. It might mean that resources devoted to the education of primary school teachers may be diverted to other levels of education or to non-educational purposes. Or it might mean that the quality of education could be increased, eg, by training better teachers or by reducing the number of primary students per primary teacher.

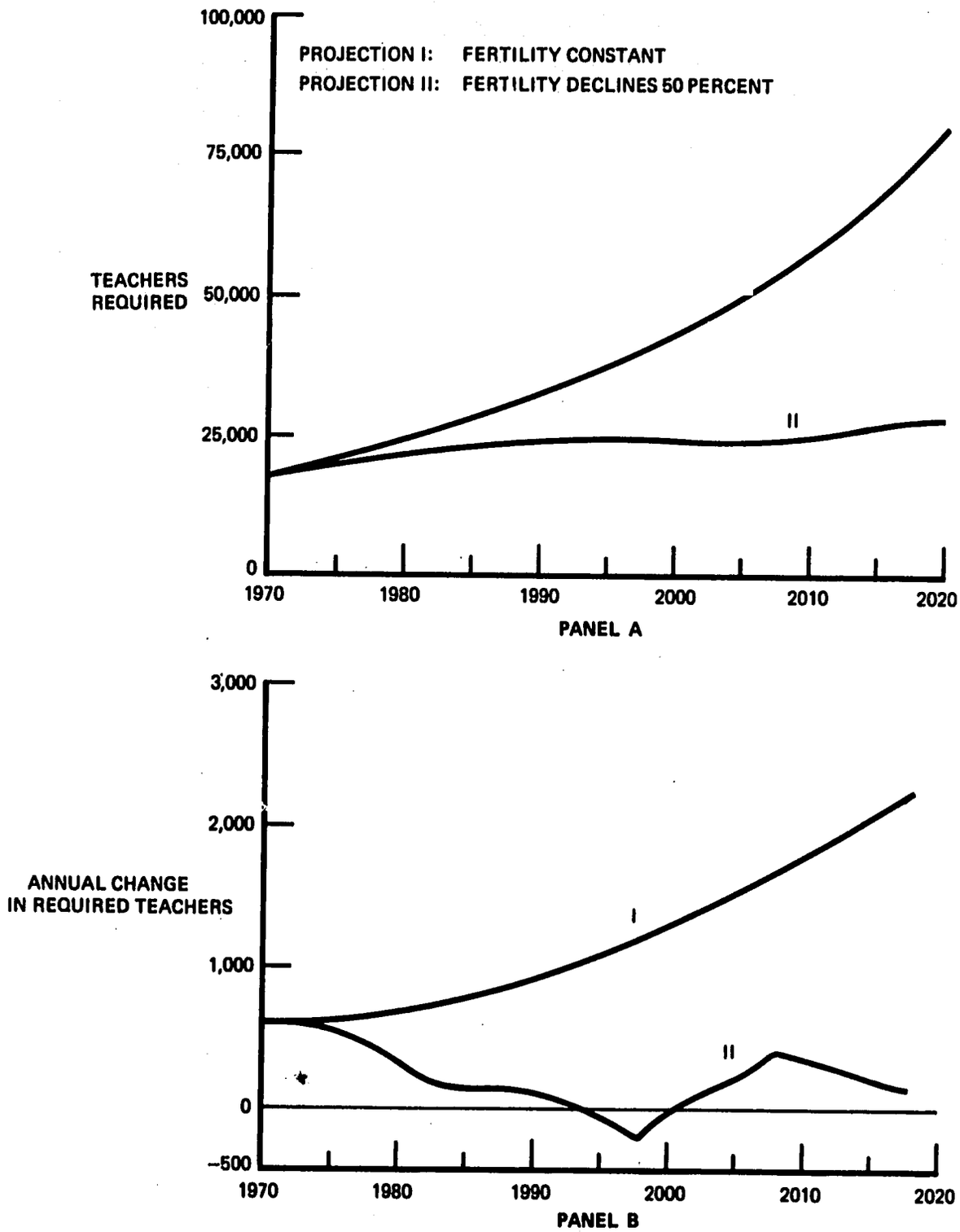


Figure 4-2. Teacher requirements with changing fertility and constant student-teacher ratio assumptions.

Figure 4-3 illustrates the implications of reducing the ratio of students to teachers under the two fertility assumptions used for the projections of Figure 4-2. It depicts the results of three projections. The first projection simply repeats the results of the constant-fertility and constant-education parameter assumptions shown in Figure 4-2. The second projection assumes that fertility remains constant, while the ratio of students to teachers falls by one-third. The third projection assumes that fertility falls by 50 percent and the student-teacher ratio by one-third. (Other education parameters are held constant for all three projections.) Panel A shows the projections of primary teacher requirements, and Panel B shows the projections of the demand for new primary teachers.

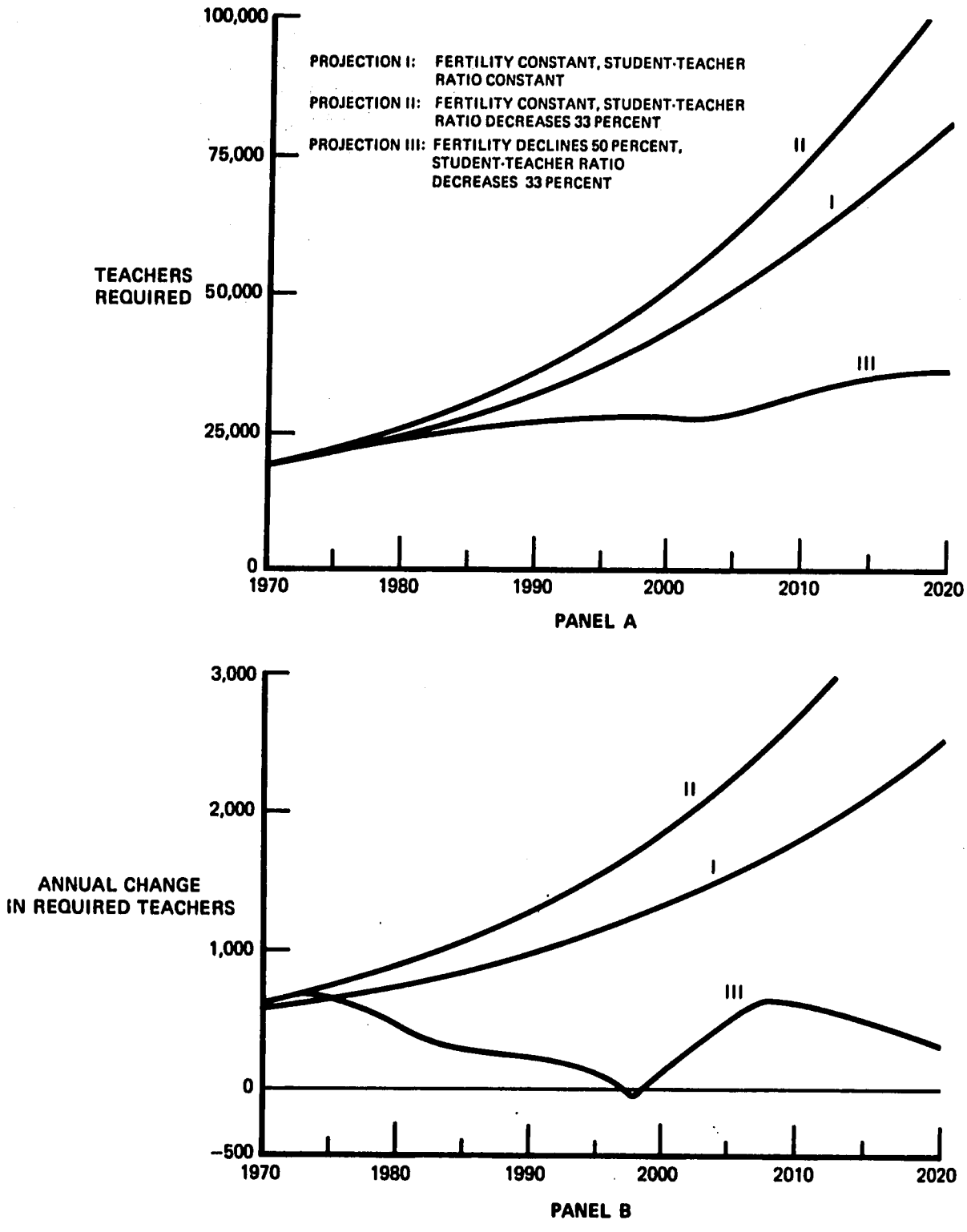


Figure 4-3. Teacher requirements with changing fertility and changing student-teacher ratio assumptions.

Exercise C4-2. Declining Fertility

This exercise is designed to show the effects of changing demographic conditions on the configuration of the educational system. The education projection uses the population projection of Exercise C2-3. That population projection is needed to interpret the output of this exercise. The basic assumptions are given as part of the projection.

1.@ Plot primary enrollment from this projection and from Exercise C4-1. Explain why they are identical from 1970 to 1975 and are different thereafter.

2.@ Graph the following series from the projection:

   a. Teachers demanded

   b. New teachers demanded

   Which series is more sensitive to changes in the growth of enrollments? Why?

3. What changes in the student-teacher ratio would give you the same number of total teachers required at the end of the projection in Exercise C4-1?

4. On the same graph as question 2b, plot the graduates from the tertiary level. Assuming that 20 percent of them would like to teach at the primary and secondary levels, plot the available supply of new teachers. What are the implications of your findings for educational planning?

Exercise C4-3. Qualitative Improvements

Next, two additional projections are made with the demographic conditions assumed in Exercise C4-1 and C4-2, but with substantial improvement in enrollments, advancement rates, and student-teacher ratios. The basic assumptions used in this projection are listed on the computer printout.

Compare this set of projections with those produced in Exercises C4-1 and C4-2, and answer the following questions:

1. Compare the constant-fertility projection of Exercise C4-1 with the declining-fertility case of this exercise. Let the number of teachers required to staff the system be a measure of the economic costs of one educational configuration compared with another. What is the saving in required teachers as a result of the fertility decline? How many additional

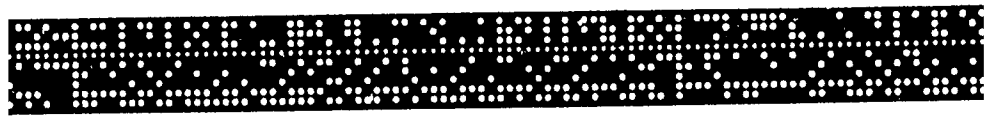
pupils could be enrolled if the supply of teachers remained constant, ie, if the resource savings were all devoted to expanding enrollments?

2.@ Repeat questions 3 and 4 of Exercise C4-2 using these new projections. Compare the results with your previous graphs.

3. Calculate the proportion of graduates from tertiary school that must go into teaching to meet the teacher requirements in the following projections:

		1985	2000
a.	Constant fertility	_____	_____
b.	Declining fertility	_____	_____
c.	Constant fertility with a falling student-teacher ratio	_____	_____
d.	Declining fertility with a falling student-teacher ratio	_____	_____

4. Consider how the demands for skilled labor in education might conflict with demands from other sectors in the economy if economic development is to take place.



Exercise C4-4. Student Control Over Parameters

This exercise is designed to further investigate interactions between fertility and improvements in educational targets. The user may change the final values of any of the educational parameters and the demographic assumptions.

Suggested Experiments

1. Find a fertility decline that will offset the additional demand for teachers generated by a reduction in the student-teacher ratio from 40 to 30 over 30 years. Use the constant-fertility projection of Exercise C4-1 as a reference here and in question 2 following.

2. Find a decrease in the primary enrollment ratio that will generate the same reduction in demand for teachers as the decrease in fertility in the case above. To solve, set the student-teacher ratio equal to 40 and the period of decline of the

enrollment ratio equal to 50 years. Then set the student-teacher ratio equal to 30. What will be the decrease in primary enrollment ratio necessary to keep demand for new teachers near zero?

3. Use existing projections and generate new ones to investigate how teacher requirements are affected by each of the following:

   a. An increase in fertility
   b. A decrease in infant mortality
   c. An increase in the primary enrollment ratio
   d. An increase in the primary-to-secondary advancement ratio
   e. An increase in the secondary-to-tertiary advancement ratio.

PROJECTING THE COSTS OF EDUCATION

Teacher and classroom costs are two of the most important components in the total cost of attaining educational goals. Teacher costs consist, for present purposes, of the salary and other costs of maintaining a current staff of trained teachers, SALARY, and the costs of training teachers, TRAINING. The projection model assumes that these costs are proportional to the total number of teachers required and the new teachers required, respectively:

$$SALARY_t = pay \cdot TEACHERS_t \tag{9}$$

$$TRAINING_t = trcost \cdot NEWTEACHERS_t \quad , \tag{10}$$

where pay is the annual cost of maintaining one teacher and trcost is the total cost of training an additional teacher. For purposes of Equation 10, $NEWTEACHERS_t$ is converted from a 5-year total given by Equation 8 to an annual average applicable to the year t.*

Classroom costs are calculated in a parallel fashion. The required number of classrooms is proportional to enrollments:

$$ROOMS_t = csr \cdot ENR_t \quad , \tag{11}$$

where csr is the ratio of classrooms to students; this is the reciprocal of the ratio of students to classrooms that is more commonly seen.

Classroom costs consist of the costs of maintaining existing classrooms, MAINTAIN, and the costs of building new ones, CONSTR. These are proportional to the number of classrooms required and the increase in classrooms required, respectively:

$$MAINTAIN_t = maintcost \cdot ROOMS_t \tag{12}$$

$$CONSTR_t = constrcost \cdot NEWROOMS_t \quad , \tag{13}$$

where maintcost and constrcost are the respective unit costs of maintaining and constructing classrooms, and NEWROOMS is the annual rate of construction.

The total education budget projected by the model, ED, is the sum of the teacher and classroom costs:

$$ED_t = SALARY_t + TRAINING_t + MAINTAIN_t + CONSTR_t . \tag{14}$$

---

* As noted earlier, the replacement of teachers lost to death and retirement is ignored, resulting in a downward bias for projected training costs.

Review Questions

Three education budgets for the years 1985-2010 are presented in Table 4-1. Countries A, B, and C have the same initial population. The educational parameters differ among the three countries but are constant for each over time. Anwer the following questions and explain your reasoning:

1. Which country's population is growing more rapidly?
2. If fertility is suddenly cut in half in 1995, which of the countries is likely to have excess capacity in the future if classroom construction and teacher training continue at 1990-95 rates?
3. Which country appears to have a declining fertility rate?

Table 4-1. Educational budgets for three hypothetical countries (costs are in millions of dollars)

	Country A	Country B	Country C
1985	10	25	35
1990	15	24	25
1995	20	23	25
2000	25	23	25
2005	30	22	20
2010	40	23	15

4. How would improving the quality of education affect these budgets?
5. How would lowering the retirement age of teachers affect these budgets?

Exercise C4-5. Education Budget Projections

Repeat the projections of Exercises C4-1 and C4-2, requesting that the table for educational costs be printed.

1.@ Graph the following series from the two projections:

TRAINING (COSTS)

SALARY

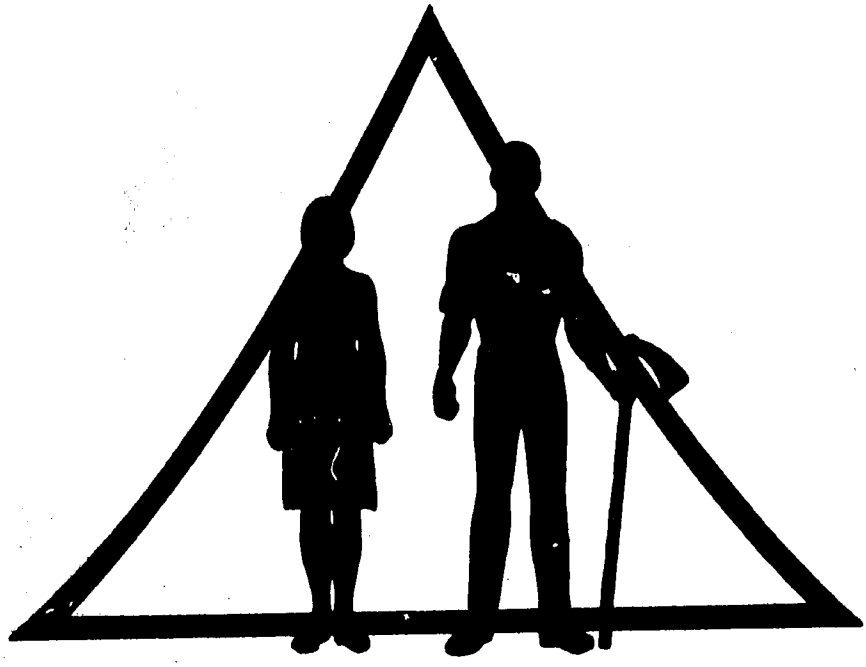
TOTAL (EDUCATION BUDGET)

Which of these is more sensitive to changes in the fertility assumptions?

Compare the graph drawn for the preceding question with graphs drawn for questions 2 of Exercise C4-2 and C4-3. Without running additional projections, sketch a graph of the TRAINING, SALARY, AND TOTAL series, corresponding to the graph drawn for question 1 of this exercise but assuming that the ratio of students to teachers falls by one-third during the projection.

CHAPTER 5

THE IMPACT OF DEMOGRAPHIC CHANGE ON THE LABOR FORCE AND UNEMPLOYMENT



THE IMPACT OF DEMOGRAPHIC CHANGE ON THE LABOR FORCE AND UNEMPLOYMENT

INTRODUCTION

The size, composition, and growth of the labor force are important determinants of the gross national product. Future changes in the labor force should, therefore, be carefully analyzed for their possible implications for output growth. It is also necessary to anticipate the future course of the labor force, so that plans can be formulated to provide productive employment for new entrants into the labor force. This chapter is devoted to an analysis of changes in the labor force and employment that result from certain demographic changes.

THE AGE COMPOSITION AND THE DEPENDENCY RATIO

The demographic forces that affect the overall population growth rate also affect the growth rate of the work-age population from which the labor force is drawn. Decreases in fertility (or infant mortality), however, affect the work-age population only after a 15- to 20-year lag. This lag has important economic implications.

Eventually, when the age distribution stabilizes, the work-age population and the total population will grow at the same rate. But during the transition from a high-fertility schedule to a lower one, the work-age population grows faster than the general population. This causes the ratio of dependent-age to work-age population to decrease, thereby producing a potentially advantageous bulge about the middle of the age distribution such as is shown in Figure 5-1. A convenient indicator of this age redistribution is the *dependency ratio,* usually defined as one of the following:

$$\text{Child dependency ratio} = \frac{\text{population in ages 0-14}}{\text{population in ages 15-64}}$$

or

$$\text{Total dependency ratio} = \frac{\text{population under age 15 and over age 64}}{\text{population in ages 15-64}}$$

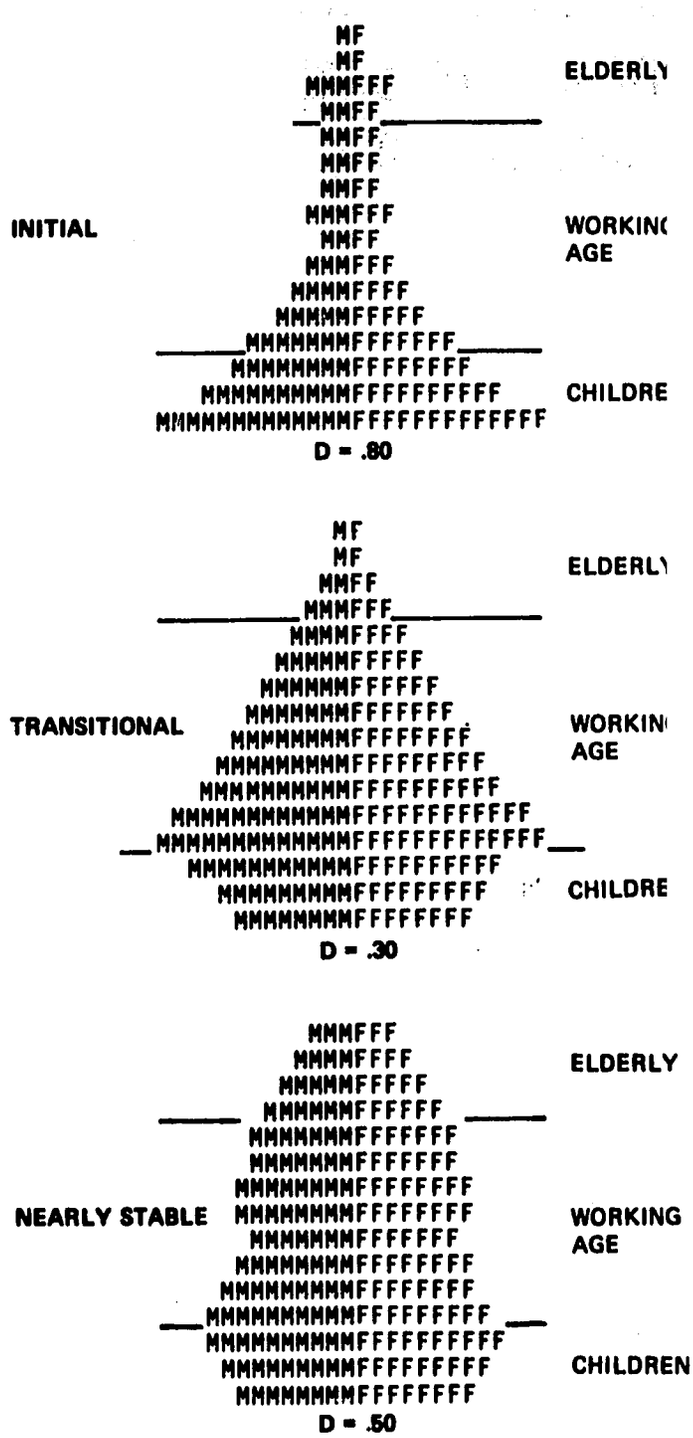


Figure 5-1. Age distribution and child dependency ratio (D) with a decline fertility (the fertility decline depicted is unusually dramatic, for illustrative purposes).

LABOR FORCE: DEFINITION AND MEASUREMENT

The labor force, or the economically active population, comprises all those persons who contribute to the supply of labor for the production of economic goods and services. Thus, it includes the employed and those who are unemployed but seeking work. The identification of the economically active population poses problems, particularly in economies where the role of the market is less prominent. Large numbers of persons in these countries are engaged primarily in producing food or other products for consumption by their own families. Since they do not receive wages for work done, the distinction between economic and noneconomic activity is not clear-cut and involves subjective judgment. This should be carefully noted while making comparisons between developed and developing countries.

LABOR FORCE PARTICIPATION RATES

Not all persons, even in the working ages, participate in the labor force. The participation rates vary by age and sex, and they are different for different countries. However, some generalizations can be made. The participation rates by age are generally higher for males than for females. Also, the rates for males in the middle adult ages (25-54) are close to 100 percent for all countries. At the upper and lower ends of the age span, the rates are generally lower for the industrialized countries than for the agricultural countries. A comparison of the age-specific participation rates for males and females in agricultural and industrialized countries is provided in Figures 5-2 and 5-3, respectively.

PROJECTING THE LABOR FORCE

To project the labor force we combine population projections and projected labor force participation rates. The projected population in each age-sex category is multiplied by the corresponding participation rate to obtain the projected labor force. Thus, for example, the male labor force of ages 30 through 34 is the product of the male population ages 30 through 34 and the labor force participation rate for those ages. The participation rates used for Developa and presented in Table 5-1 are the average rates for the agricultural countries given in the United Nations report on *Demographic Aspects of Manpower.** We assume for the sake of simplicity that the participation rates remain constant and that they are zero for the age groups under 15 and over 64.

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* United Nations, *Demographic Aspects of Manpower*, New York, 1962.

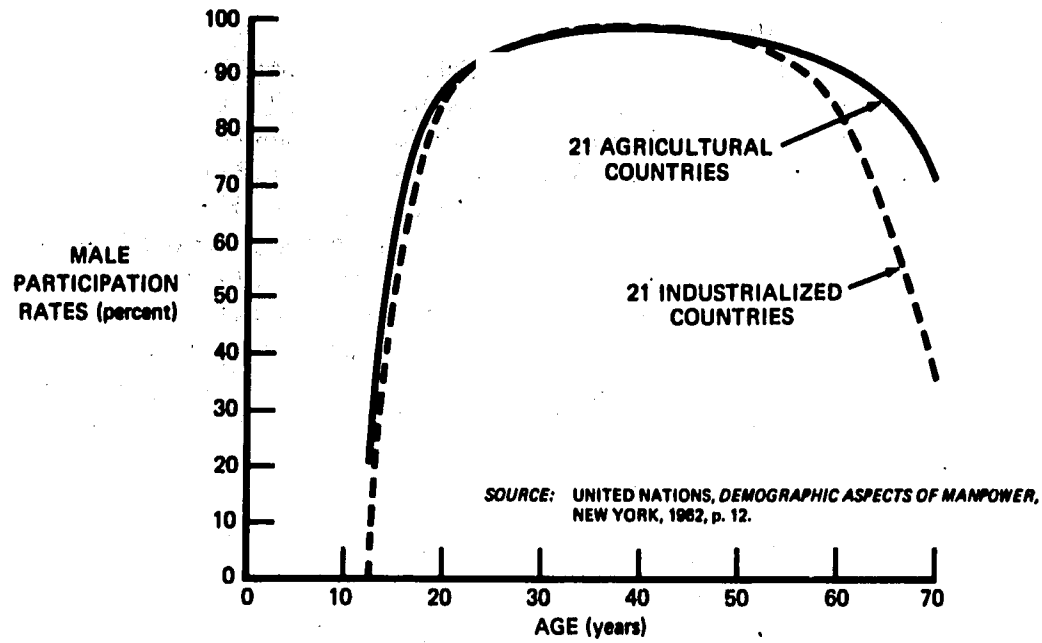


Figure 5-2. Average male participation rates by age for agricultural and industrialized countries.

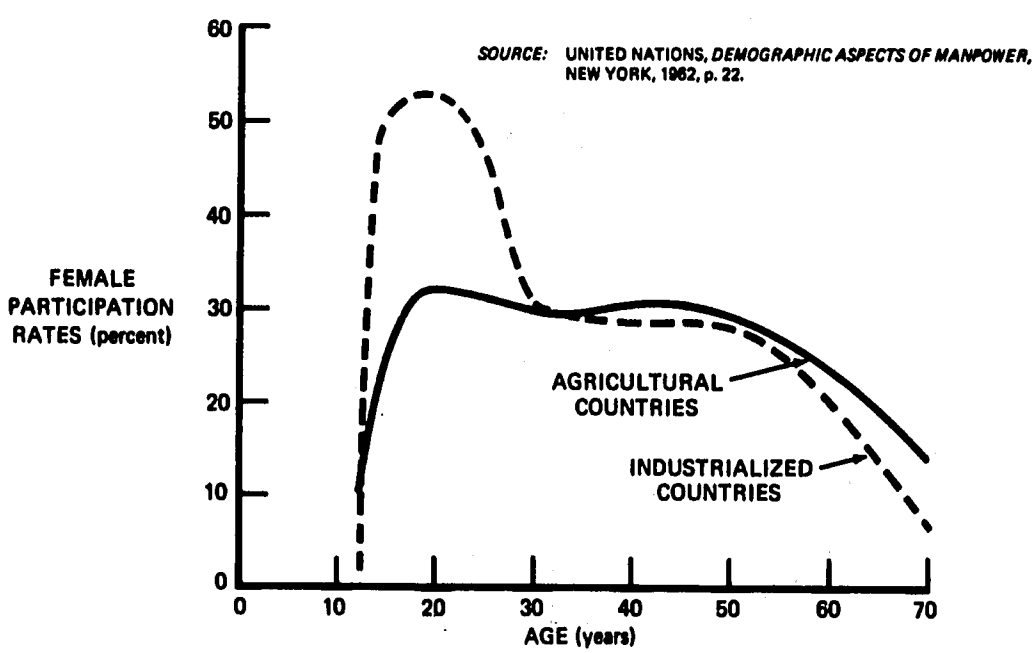


Figure 5-3. Average female participation rates by age for agricultural and industrialized countries.

Table 5-1. Labor force participation rates.

Ages	Males	Females
15-19	0.78	0.31
20-24	0.91	0.32
25-29	0.96	0.30
30-34	0.96	0.30
35-39	0.98	0.31
40-44	0.98	0.31
45-49	0.96	0.29
50-54	0.96	0.29
55-59	0.92	0.24
60-64	0.92	0.24

The results of two labor force projections using these participation rates are compared in Figure 5-4. The first projection assumes that fertility remains constant (with a GRR of 3.0), and the second assumes that fertility declines by 50 percent over the first 25 years of the projection (to a GRR of 1.5) and then remains constant. The additional jobs required per year under the two projections are shown in Figure 5-5. As the figures clearly

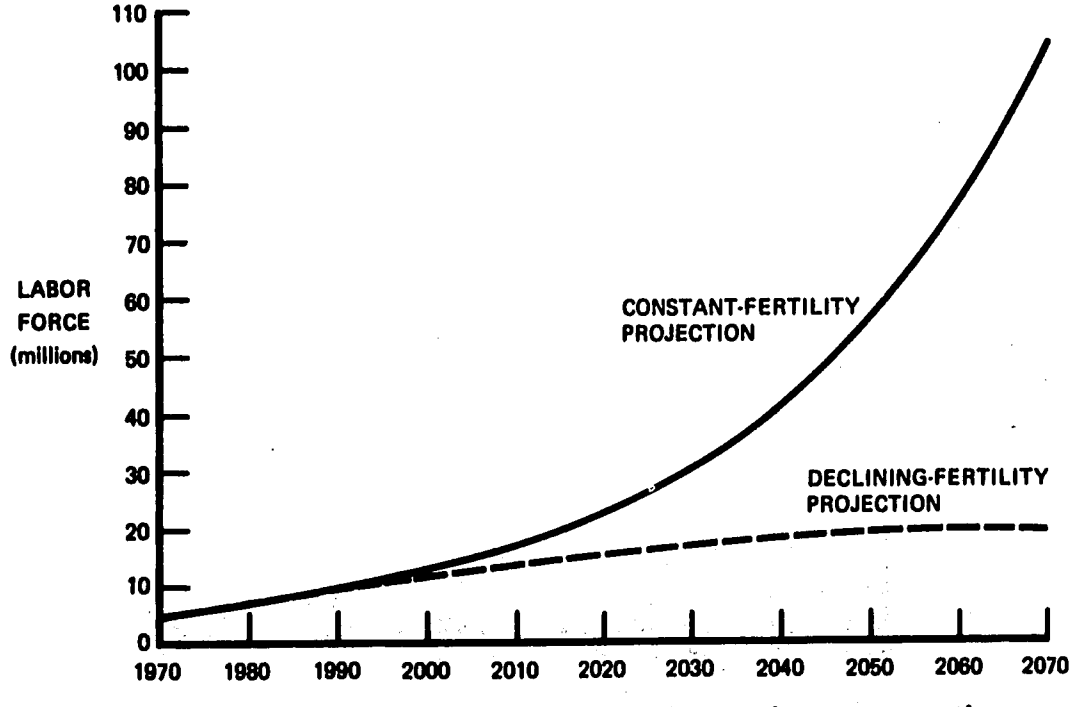


Figure 5-4. Projected labor force for Developa under constant and declining fertility assumptions.

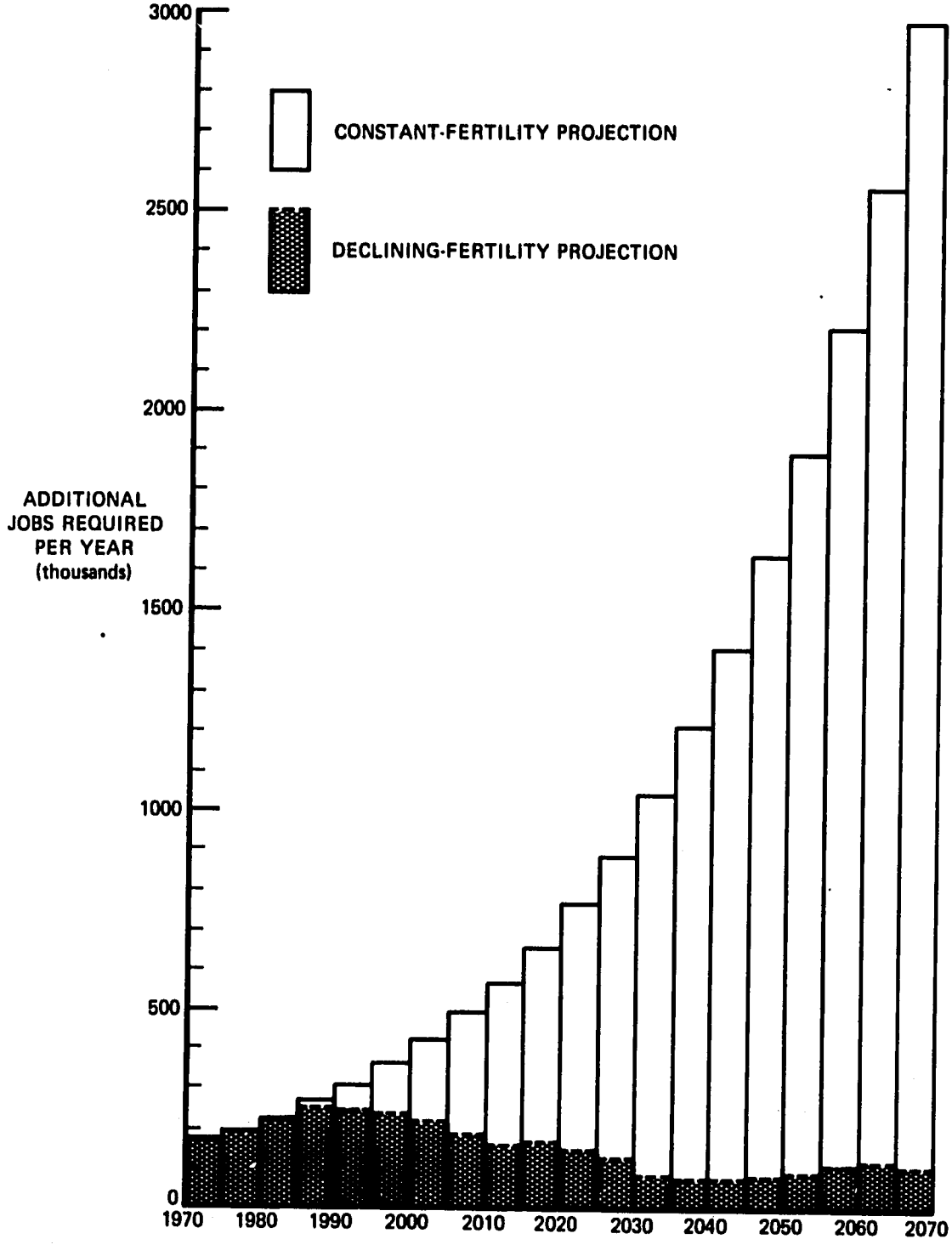


Figure 5-5. Additional jobs required under constant fertility and declining fertility assumptions.

show, the two projections do not differ for the first 15 years. But thereafter the number of jobs required under declining fertility is less than under constant fertility.

Figure 5-6 illustrates that as fertility declines the labor force grows faster than the population, so that the proportion of the total population in the labor force rises. As fertility stabilizes, however, the ratio of labor force to population declines somewhat, but then becomes stable at a value significantly higher than is present in the projection with constant high fertility.

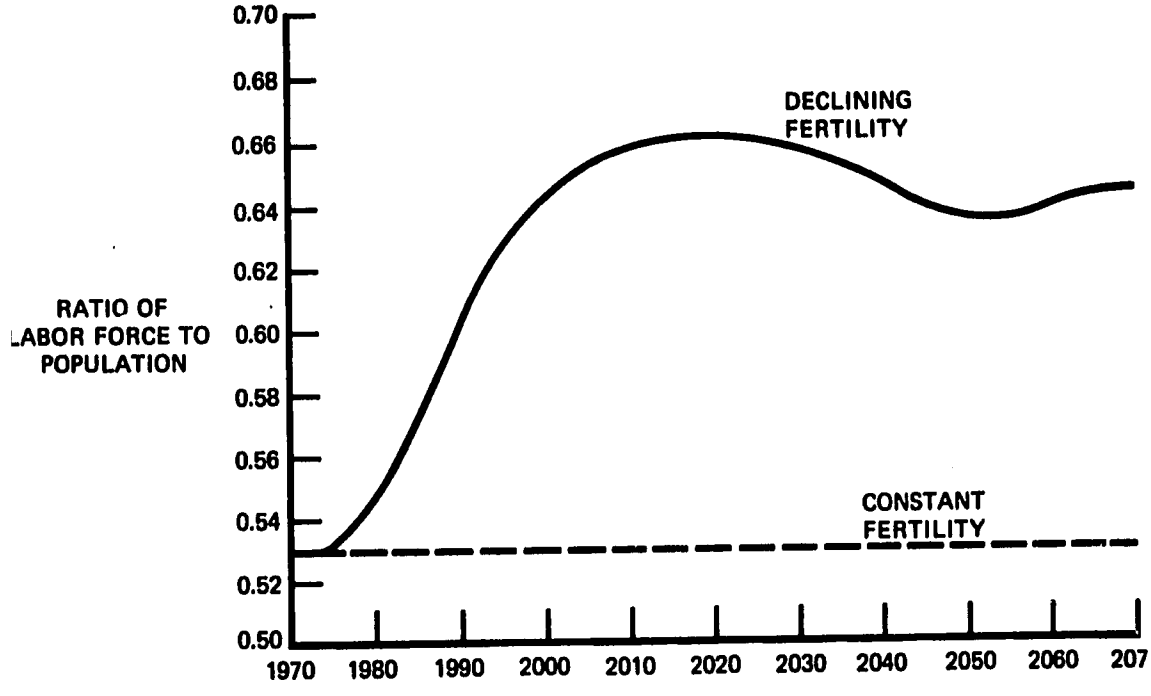


Figure 5-6. Ratio of labor force to population for Developa under constant and declining fertility.

LABOR FORCE AND UNEMPLOYMENT

One of the important facets of economic-demographic planning is to anticipate future changes in the labor market to minimize the social costs associated with imbalances between the supply of and demand for labor. Labor force projections provide valuable information on the probable additions to the labor force during specified future time periods, so that plans can be formulated in advance for dealing with the anticipated growth of the population seeking employment.

In many countries there is a backlog of unemployed and underemployed* persons that constitutes a political and social problem and a wastage of potentially productive resources. To reduce unemployment and the unemployment rate (ie, percentage of unemployed in the labor force), employment must grow faster than the labor force in those countries.

Consider a numerical example. Suppose that the labor force is presently 100,000 in number and is growing 3 percent per year. Also suppose that 20 percent of the labor force is currently unemployed. If employment also rises by 3 percent annually, we find that the unemployment rate remains unchanged at 20 percent (see Table 5-2). If, instead, employment grows at 4 percent annually, the unemployment rate drops to 12 percent in 10 years. If employment grows by only 2 percent per year, however, the unemployment rate reaches 27 percent by the end of the decade.

Table 5-2. Changes in the unemployment rate.

Initial Unemployment (percent)	Annual Growth Rate of Labor Force (percent)	Annual Growth Rate of Employment (percent)	Unemployment Rate 10 Years Later (percent)
20	3	2	27
20	3	3	20
20	3	4	12
20	3	5	3

The same results can be obtained using the formula given below. Expressed in algebraic form, the unemployment rate after n years, u_n, is given by

$$u_n = \frac{L_o (1 + r)^n - E_o (1 + s)^n}{L_o(1 + r)^n} \qquad (1)$$

where L_o and E_o are the labor force and the employment respectively in the initial period, r and s are the average annual growth rates of labor force and employment, respectively, and n is the number of years from the initial period. Equation 1 can also be expressed as

$$\frac{(1 - u_n)}{(1 - u_o)} = \frac{(1 + s)^n}{(1 + r)^n} \qquad (2)$$

* A person is considered underemployed if he involuntarily works part time or if his job does not permit full use of his highest existing skill or capacity. While underemployment is a useful concept, to measure the rate of underemployment is very difficult.

where u_o is the unemployment rate in the initial period. Equation 2 can be used to estimate the required growth rate of employment, s, needed to reach the target rate of unemployment, u_n, in n years, if the growth rate of the labor force, r, and the present unemployment rate, u_o, are known.

Suppose, for example, the present unemployment rate in Developa is 20 percent and the labor force is growing at an annual rate of 3 percent. Also suppose that the government has set a target of reducing the unemployment rate to 10 percent within 10 years. What is the required growth rate of employment needed to attain the target? Substituting the values of $u_o = 0.20$, $r = 0.03$, $u_n = 0.10$, and $n = 10$ in Equation 2, we estimate the required growth rate of employment, s, as 4.2 percent.

POPULATION GROWTH AND UNEMPLOYMENT

Many developing countries are experiencing high rates of population growth caused by rapid declines in mortality in recent decades and nearly constant high fertility. Although the mortality decline is intrinsically desirable as an end in itself, it has certain adverse effects on unemployment. With declining mortality, more children survive to the working ages and seek jobs. Thus, rapid population growth generally aggravates the already serious problems of unemployment. On the one hand, rapid growth tends to make investment more difficult, which in turn hampers the creation of new jobs. On the other hand, it assures the entrance of ever increasing numbers into the labor force each year.

Slowing population growth via fertility reduction will reduce the growth of new entrants to the labor force, but the effect is not felt for some 15 years after the fertility decline since that is the time required for today's babies to enter the labor force in any significant numbers. On the other hand, declining fertility may encourage increasing numbers of females to seek jobs, resulting in a short-run acceleration in labor force growth. Whether such an infusion of new workers into the labor force has salutary effects on the economy depends on how well the country overcomes traditional structural rigidities in the labor market. In any case, increased production and investment are necessary to transform a growing labor force into useful employment in both the short run and the long run.

Questions

1. Are labor force and work-age population the same? If not, how do they differ?
2. Declining fertility produces a (decrease, increase) in the labor force/population ratio. Why? What will be the effect of declining infant/child mortality on the ratio, assuming constant fertility?
3. In Figure 5-4 the projected labor force is identical under constant fertility and declining fertility for the first 15 years. Why?

Exercise C5-1

In this exercise the computer produces two 50-year projections of the child and work-age populations and the labor force for a given country under different fertility conditions. The first projection assumes constant mortality and fertility, while the second assumes constant mortality and declining fertility. Use the resulting projections to answer the following questions:

1.@ Plot the projected child and work-age populations on a graph for each of the projections.
2.@ Plot the child dependency ratios for the two projections, ie, POP(0-14) ÷ POP(15-64).
3. Explain the changes in the child dependency ratio in terms of the changes in the child and work-age populations.
4. Plot the labor force in each projection given an initial unemployment rate of 20 percent, and find the rate of growth of employment required to reduce unemployment to 10 percent in 30 years in both constant and declining fertility runs. Plot the implied employment projections on the same graph.

Exercise C5-2

In this exercise the computer makes a 50-year projection of the labor force for a given country under the assumption that infant-child mortality declines substantially during the projection.

1.@ Draw a graph comparing this projection with the constant mortality and fertility projection of Exercise C5-1.

2.@ Draw another graph showing the additional jobs required every year (assuming full employment) under the two projections.

3. How do these projections differ from the declining-fertility projection?

Exercise C5-3

Repeat Exercises C5-1 and C5-2, entering your own fertility and mortality assumptions for the computer projections.

RELATING DEMOGRAPHIC CHANGE TO ECONOMIC DEVELOPMENT AND PUBLIC EXPENDITURES

INTRODUCTION TO PART III

Part I focused on the dynamics of demographic change, and Part II showed how such change might affect the demands for jobs and social services. Part III explores the effects of demographic change on the growth of gross national product (GNP) and GNP per capita. Both economic and demographic changes are further related to alternative patterns of government expenditure. Each commitment of funds and resources to a given sector implies a cost measured in terms of foregone goods and services in the other sectors. Changes in the size and age structure of the population will alter these tradeoffs.

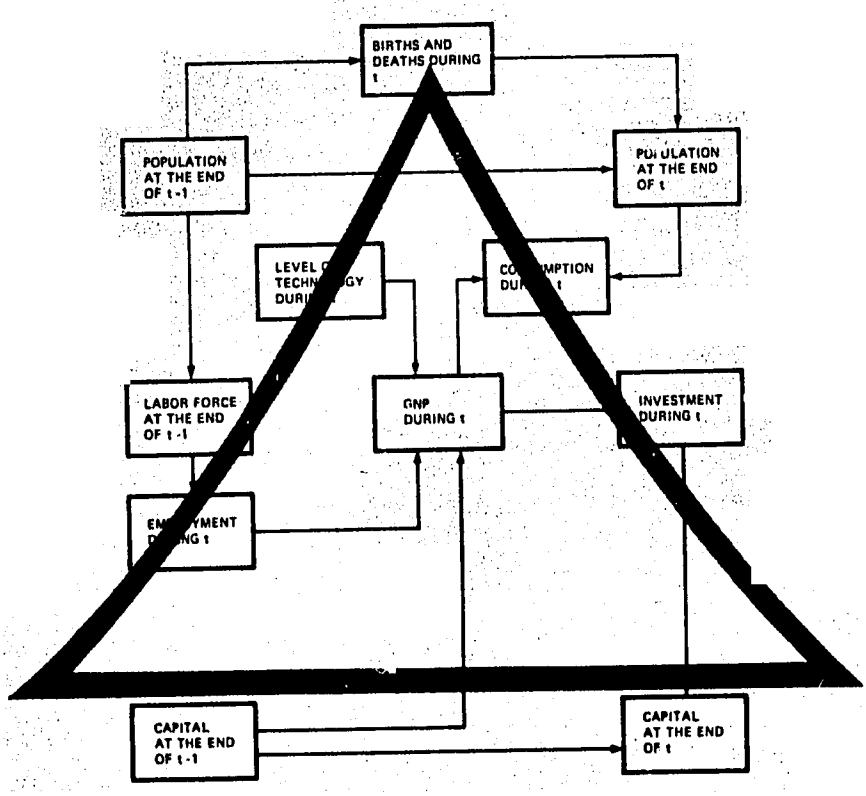
The material introduced in Part III is considerably more technical than that presented in the previous parts. In general, we try to take advantage of the reader's prior knowledge of the popular uses of economic terminology. It will be largely taken for granted, for instance, that the reader understands such concepts as capital or gross national product, which are widely used in nontechnical publications. Readers with limited background in economics, however, must rely more heavily on assistance from the instructor than was necessary in Parts I and II.

Chapter 6 presents a simple economic model that relates the growth of total production to the growth of capital and labor, and shows how the growth of these resources is related to the patterns of demographic change. Although the reader may have little basis for evaluating the particular way in which the growth of GNP is related in the projection model to the growth of inputs of labor and capital, he can observe by experimentation that the projection results are consistent with a wide range of conditions.

In Chapter 7 a government sector is added to the basic economic model of Chapter 6. This addition permits the exploration of a number of different tradeoffs that result from alternative allocations of resources within the economy. For example, the implications of a particular split of GNP between the public and private sectors are investigated by altering the tax rate. Such changes can affect the rate of capital accumulation, among other things, and thereby alter the long-run growth of total output and consumption. Other tradeoffs are investigated for the public sector. For example, more funds can be spent on education and less on investment, with corresponding implications for the growth of GNP, per capita GNP, and consumption.

CHAPTER 6

THE AGGREGATE ECONOMIC MODEL



THE AGGREGATE ECONOMIC MODEL

INTRODUCTION

This chapter presents an economic projection model for investigating the impact of demographic change on total output and other aggregate economic variables. Following a discussion of several important aggregate measures of economic change, the model is presented—first in brief, then in more detail. The final section of the chapter presents a framework for analyzing how changes in demographic conditions affect the growth of total output.

KEY ECONOMIC VARIABLES

Economic activity is commonly measured in terms of highly aggregated variables. The most important of these treated by the projection model are:

1. Gross national product, a measure of total output
2. Labor force and employment, measures of the direct human resources available and used in production
3. Capital, a measure of the man-made materials used in production, eg, factories
4. Consumption, a measure of the production used for the direct satisfaction of human wants
5. Investment, a measure of the production used for additions to productive capital.

While these variables are very useful measures of economic activity, each is highly aggregated and therefore needs to be used with a certain sense of caution. The heterogeneity of the components (eg, individual households) that determine and comprise the aggregates increases the potential errors associated with the use of these variables. Results from aggregate models are best used in combination with a closer investigation of the related components. This caveat is especially pertinent when the model is applied to a developing country, where the very nature of development involves changing the nature of the micro-relationships and the composition of the aggregates.

Gross National Product

The gross national product, or GNP, is the most commonly used measure of the total output of a country.* Ideally, it measures the total value of all goods and services produced in a given year. In using measured GNP, care should be taken to determine if important nonmarketed output (eg, household produced and consumed output) has been included. Nonmarketed production may be particularly important in low-income agricultural economies.

Labor Force and Employment

The concepts of labor force and employment have been discussed in Chapter 5. The total labor force is measured solely in terms of the number of workers. All members of the labor force rank equally in the model, regardless of age, sex, or skills.

Employed labor is measured in terms of full-time equivalents. Two available laborers make the same contribution to employed labor when both are employed half-time as when one is employed full-time and the other is completely unemployed. The difference between the total labor force and employed labor represents "underutilized available labor." "Unemployment" is frequently used here because of its brevity even though underutilized labor includes both unemployment and underemployment. The influence on labor productivity of such factors as the state of technology, natural resources per worker, education, and health is reflected in the numerical specification of the production function.

Capital

Capital is the aggregate value of all man-made material means of production. It excludes the "human capital" that results from the investment element of expenditures on such things as health and education, but includes the value of such things as roads, factories, tractors, and irrigation canals.

Consumption

Consumption is the value of all production used during a year for the direct satisfaction of human wants, ie, that does not contribute directly to the net accumulation of capital. It includes both private consumption (eg, for food and clothing) and public consumption (eg, for education

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* The gross *national* product is the value of all production from the resources owned by the citizens of a country. Another common measure is the gross *domestic* product, which is the value of all production within the borders of a country. Production within a country, A, that results from the use of resources owned by the citizens of another country, B, is counted as part of the gross domestic product of country A and part of the gross national product of country B. No distinction between the two is made in the present projections.

and health). It also includes all investment used to maintain the existing level of capital, sometimes called "capital consumption" or "replacement investment."

Investment

Investment represents the value of all production devoted to increasing capital. As used here, "investment" refers to what is commonly called "net investment," ie, it excludes replacement investment. It is also assumed that investment each year is equal to savings, ie, all production that is not consumed is invested.

DESCRIPTION OF THE ECONOMIC MODEL

The Economic Model in Brief

Demographic projections generate the population by age and sex for every 5 years. These are converted to annual projections by linear interpolation for use by the economic model. Combined with age- and sex-specific labor force participation rates, they give the size of the labor force each year of the projection.

The proportion of the labor force employed each year is prespecified. The initial values of employed labor and capital (representing all of the economy's means of production, including plant and equipment) determine the gross national product (GNP) during the first year of the projection.

The year's GNP is divded between total consumption and net investment. The size of consumption is determined by the level of GNP and size of the population. The portion of GNP not consumed represents *net* investment, ie, is an addition to capital.

The sum of the capital available at the beginning of the year and net investment during the year gives the capital available at the beginning of the next year. The available capital and employed labor determine the economy's GNP during the following year. Technological progress is introduced by increasing by a fixed percentage each year the GNP resulting fror any given amount of capital and labor. The process is repeated each year for the duration of the projection.

Figure 6-1 is a simplified flowchart showing how the values of demographic and economic variables at the end of a year (t − 1) determine the values of the desired variables for the next year (t).

Production Function

The formal relationship assumed between total output or GNP and the inputs of capital K and employed labor N is a production function of the form

$$GNP_t = z(1+q)^t \cdot K_{t-1}^u \cdot N_{t-1}^v \qquad (1)$$

The exponents u and v measure the percentage increases in output that occur from a 1 percent increase in each of the respective inputs. For

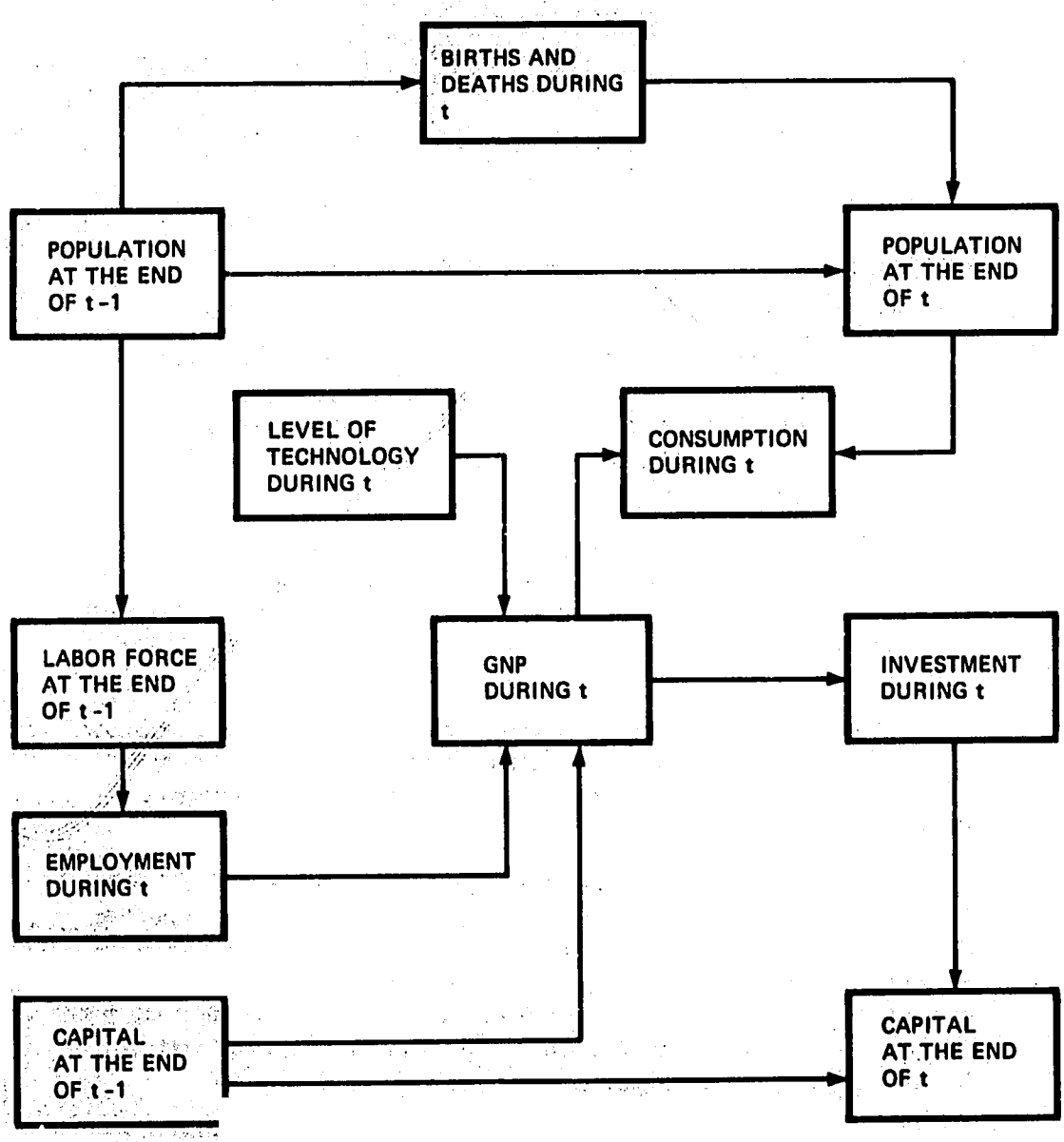

Figure 6-1. Flowchart of basic computer sequence.

example, if capital is increased by 1 percent and labor held constant, output increases by u times 1 percent. If capital and labor are both increased by 1 percent, then output should increase by (u + v) percent.

The parameter q measures the rate of technological progress, ie, the rate at which the output from any combination of capital and labor increases due to advances in technology. If there is technological progres of 0.005, the same inputs of capital and labor produce 0.5 percent more output each year.

It is assumed that labor and capital must work together in the prc duction process, though not necessarily always in the same proportions. Different combinations of capital and labor can produce the same level of output, ie, capital and labor may substitute for one another. For example, two men and two machines might produce the same amount as four men and one machine.

While output increases as only one input is increased and the othe is held constant, the resulting incremental gains in output eventually decline. In formal economic terminology, this property is called *declining marginal productivity.* If both inputs increase together, output increases less than proportionally, proportionally, or more than proportionally depending on whether conditions of decreasing, constant, or increasing returns to scale prevail. If labor and capital increase at the same rate, meaning each laborer works with the same amount of capital as before, then a near proportional increase in output (ie, constant returns to scale) is commonly expected. Whether it is actually proportional or not will vary somewhat from situation to situation.

In the model, the presence of decreasing, constant, or increasing returns to scale depends on whether the sum of u + v is less than, equal to, or greater than unity. For example, assume that u and v are 0.40 and 0.60, respectively. Then assuming no change in technology, a 2 percent increase in both labor and capital also increases output by 2 percent. Constant returns to scale prevail. If the values were 0.3 and 0.6, respectively, then the 2 percent increase in each input results in an output increase of approximately 1.8 percent.* Decreasing returns to scale prevail.

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* As an approximation, the percentage increase in GNP that results from given percentage increases in capital and labor can be obtained by adding the products of the percent increase of each input with its corresponding exponent, u or v. Thus, the percent increas in GNP resulting from a 2 percent increase in both labor and capital is approximately equal to 2u + 2v percent. If u and v are 0.3 and 0.6, respectively, the percent increase in GNP is approximately (2 • 0.3) + (2 • 0.6), or 1.8.

Labor Force and Employment

The work-age population is translated into employed labor in the model in two stages. First, age-specific labor force participation rates are applied to the work-age cohorts of the population to calculate the available work force, according to historical trends or future expectations:

$$L_t = \sum_{i=4}^{13} \left(lfprm_i \cdot POP_{m,i,t} + lfprf_i \cdot POP_{f,i,t} \right) \tag{2}$$

where L is the toal labor force, $POP_{m,i}$ and $POP_{f,i}$ are the respective male and female populations of age cohort i, and $lfprm_i$ and $lfprf_i$ are the corre sponding labor force participation rates.

Then, a pre-specified proportion of the labor force is assumed to actually find employment. This employment rate may be varied over time:

$$N_t = n \cdot L_t \tag{3}$$

where N is the full-time equivalent employed labor force, and n is the pre-specified employment rate.

Changing demographic conditions directly affect the labor supply, as was shown in Chapter 5. Reviewing briefly, the labor force is composed of a specific age segment of the population. As fertility or mortality change, the age distribution of the population changes. The size of the work-age population will respond very little to fertility change for the first 15 to 20 years, meaning that its proportion of the total population increases for this period. Until the population stabilizes at a new growth rate, the proportion of work-age population will vary.

Capital

The capital at the end of any year (t) is equal to the capital at the end of the preceding year (t – 1) plus the amount of net investment, I, during the year:

$$K_t = K_{t-1} + I_t \tag{4}$$

Consumption

Consumption includes all private and public expenditures that contribute directly to the satisfaction of human wants, plus all expenditures for the maintenance of the existing stock of capital. Consumption is assumed to depend on the size of total production, GNP, and the size of the population, POP:

$$C_t = a \cdot GNP_t + b \cdot POP_t \quad (5)$$

The parameters a and b measure, respectively, the responsiveness of consumption expenditures to the growth of GNP (the more we have the more we consume) and population (some components of personal consumption, such as food and housing up to some minimum values, and public services, such as education, are closely related to the size of the population).

Investment

It is assumed that all production not consumed contributes to the accumulation of productive capital, ie, represents net investment, I:

$$I_t = GNP_t - C_t \quad (6)$$

The nature of the consumption function (Equation 5) implies that the ratio of net investment to GNP increases as per capita GNP grows.*

Summary of the Basic Economic Projection Model

1. $GNP_t = z(1 + q)^t \cdot K^u_{t-1} \cdot N^v_{t-1}$

   where GNP measures total output, K the stock of capital, and N the size of the employed labor force.

2. $L_t = \sum_{i=4}^{13} \left(lfprm_i \cdot POP_{m,i,t} + lfprf_i \cdot POP_{f,i,t}\right)$

   where L is the total labor force and $POP_{m,i}$ and $POP_{f,i}$ are the respective male and female population of the ith age cohorts.

3. $N_t = n \cdot L_t$

4. $K_t = K_{t-1} + I_t$

   where I is the value of net investment.

Combining Equations 5 and 6 and dividing through by GNP, we obtain the following:

$$I = (1 - a) \cdot GNP - b \cdot POP$$

or

$$\frac{I}{GNP} = (1 - a) - b \cdot \frac{1}{GNP/POP}$$

The size of the last term approaches zero as per capita GNP (ie, GNP/POP) increases, thus increasing the ratio of I to GNP.

5. $C_t = a \cdot GNP_t + b \cdot POP$

where C is the value of total consumption and POP is the size of the total population.

6. $I_t = GNP_t - C_t$

Review Questions

1. From the description of the production function, Equation 1, it is apparent that the growth of GNP depends on the growth rates of capital and labor and the rate of technological progress Figure 6-2 presents a graph of two projections that exhibit the effects of changing these three determinants. Panel A of Figure 6-2 presents a graph of the growth rates of GNP, capital, and employment for a projection in which the rate of technological progress is assumed to be 1.0 percent annually (ie, q equals 0.01). Panel B presents a graph of the same growth rates for a projection in which the rate of technological progress was assumed to be 2.0 percent annually (i.e., q equals 0.02). The growth of employment is identical in the two projections, but the growth of capital is different.

   a. Taking the growth rates of capital and employment as given, explain the shape of the circled portions on the graphs of the growth rates of GNP.

   b. What is the impact on the graphs of the different assumptions about the rate of technological progress? Sketch the growth rate of GNP for both projections, assuming that capital and employment grow as shown in Figure 6-2 but that the rate of technological progress is zero.

2. Assume that the consumption equation is given by

$$C_t = 0.85\ GNP_t + 10\ POP_t$$

   a. Write the equation for investment as a function of GNP and POP.

   b. Assume that the GNP is 2 billion and the population is 10 million. What is the level of consumption? of investment? What is the ratio of investment of GNP?

   c. If the GNP quadruples and the population doubles, what happens to the ratio of investment to GNP?

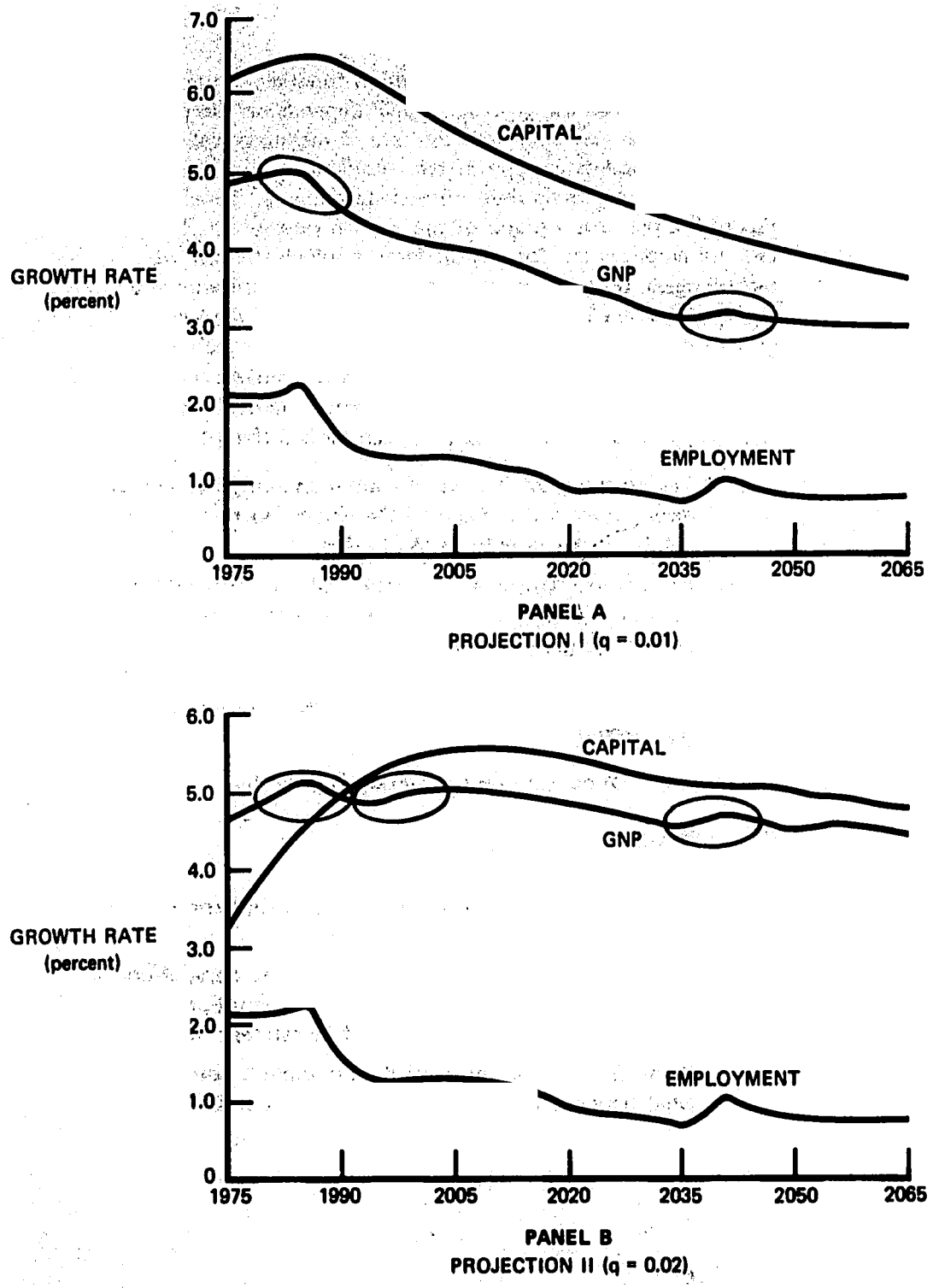


Figure 6-2. Growth rates of capital, GNP, and employment.

Exercise C6-1

This exercise uses two projections that use identical assumptions except that the coefficient for GNP in the consumption function has been substantially decreased for the second projection. The basic assumptions are supplied as a part of the projections.

1.@ Graph the projections of GNP, capital, consumption, and employment. What are the major differences between the two projections? Explain the reasons for the major differences.

2.@ Graph the projections of the growth rates of GNP, capital, consumption, and employment. What are the major differences between the two projections? Explain the reasons for the major differences.

RESPONSE OF ECONOMIC PROJECTIONS TO DEMOGRAPHIC CHANGE

Demographic change normally implies either an acceleration or deceleration of population growth and a change in the age composition of the population. The changing growth rate and age composition affect the growth of total output through their impacts on the growth of capital and labor. To illustrate the economic significance of demographic changes, the model has been used to make two projections with constant and declining fertility, all else being held equal. The resulting projections of GNP per capita are shown in Figure 6-3. As the figure shows, one effect of reducing fertility is to accelerate the growth of GNP per capita. What mechanism is primarily responsible for this change?

In addressing this question, it is useful to decompose per capita GNP into the product of three ratios: the ratio of employed labor to population, the ratio of capital to employed labor, and the ratio of GNP to capital. Thus,

$$\frac{GNP}{POP} = \frac{N}{POP} \cdot \frac{K}{N} \cdot \frac{GNP}{K} \qquad (7)$$

Any force that affects any one of these ratios will also commonly affect the others if given sufficient time. They are not independently determined. Over limited periods of time, however, the sensitivity of the ratios to specific forces may be quite different.

The Ratio of Employment to Population, N/POP

As was shown in Chapter 5, a decline in fertility tends to increase the proportion of the population in the work-ages. If labor force participation rates and the employment rate remain unaffected by the decline in fertility,* the increasing proportion of work-age population translates into an increasing ratio of employment to population, N/POP. This result is shown in Panel A of Figure 6-4.

The Ratio of Capital to Labor, K/N

Although declining fertility increases the ratio of employment to population, it tends to slow down the actual growth of employed labor after a lag of perhaps two decades. In the interim, the growth of employed labor is relatively insensitive to changing fertility conditions.

* As discussed in Chapter 5, there will be some tendancy for both labor force participation rates and employment rate to increase, reinforcing the result given above.

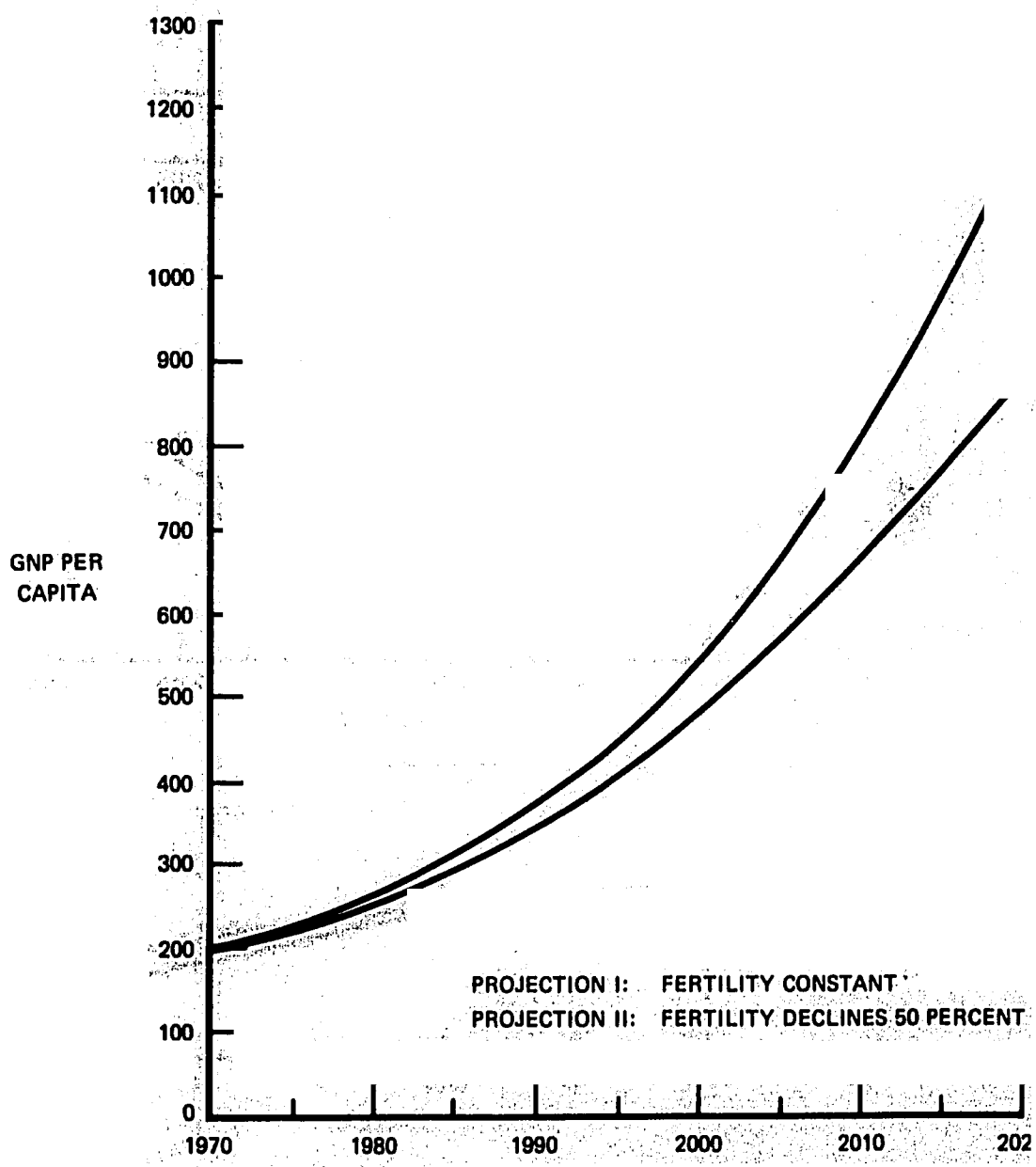


Figure 6-3. GNP per capita, constant and declining fertility assumptions.

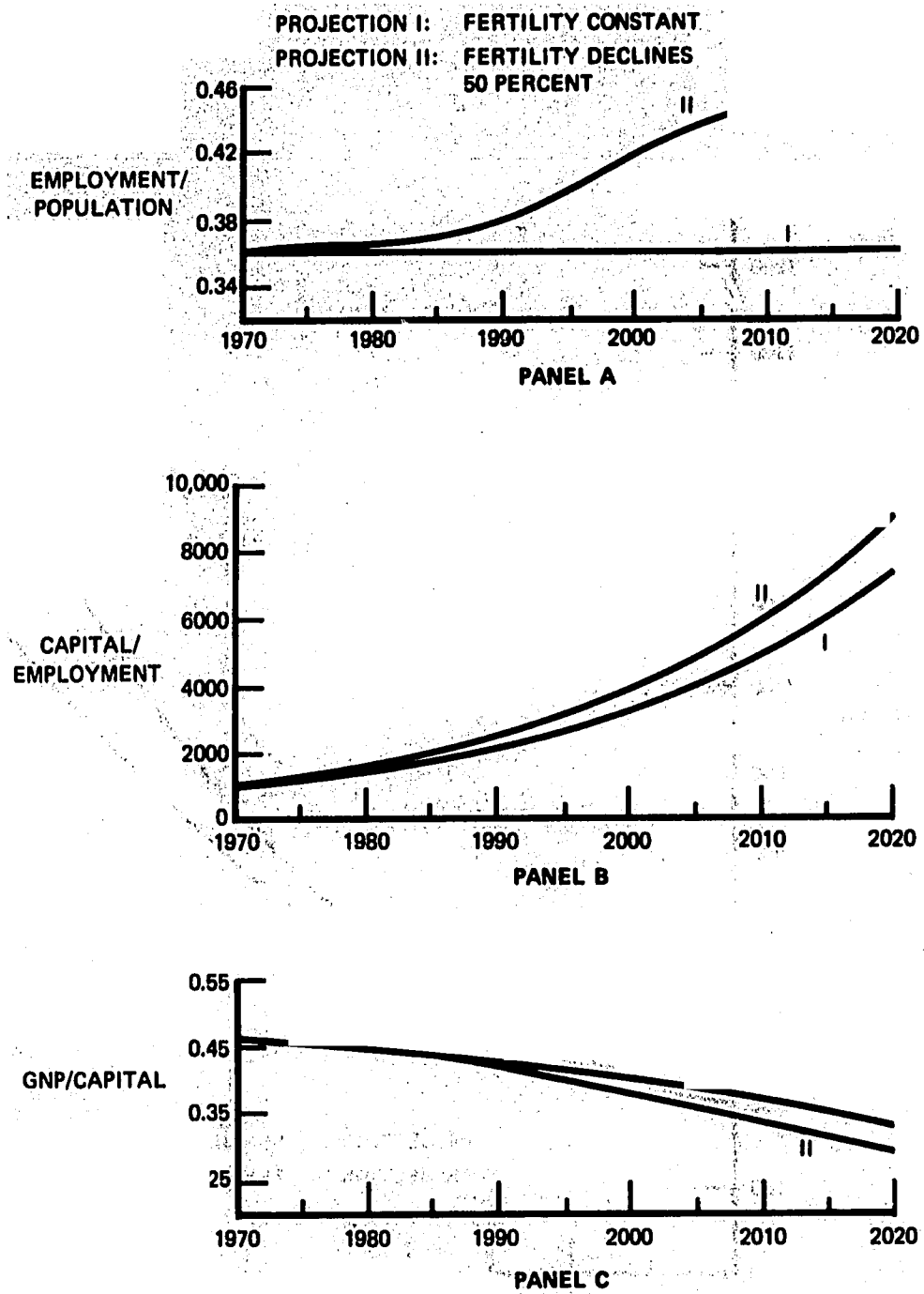


Figure 6-4. Projections of the ratios of employment/population, capital/employment, and GNP/capital under constant and declining fertility assumptions.

While the growth of employment is slowed by declining fertility, the growth of investment tends to be accelerated. This, in turn, accelerates the growth of capital. Slower growth of employment and more rapid growth of capital acts to increase the ratio of capital to employment, K/N, as shown in Panel B of Figure 6-4. This effect may be relatively small during the first decade or so of the fertility decline.

The Ratio of GNP to Capital, GNP/K

The change in the ratio of capital to labor, like the change in the ratio of labor to population, acts to increase per capita GNP. But accelerating the growth of capital relative to labor also tends to decrease the marginal productivity of capital; ie, the additional output that results from adding an additional unit of capital while holding the amount of employed labor constant (the marginal product of capital) tends to fall. The fall in the marginal productivity of capital acts to drive down the average productivity of capital, ie, the ratio of GNP to capital. This is shown on Panel C of Figure 6-4.

Thus, the net gain from accelerating the growth of capital tends to be less than is indicated by the increasing ratio of capital to labor. Over the first few decades of a decline in fertility, the increasing ratio of employment to population tends to be the most important force accelerating the growth of per capita GNP.

Review Exercise

Equation 7 can easily be modified to consider the forces changing per capita consumption, ie,

$$\frac{C}{POP} = \frac{N}{POP} \cdot \frac{K}{N} \cdot \frac{GNP}{K} \cdot \frac{C}{GNP}$$

Analyze the projection results given for Exercise C6-1 using the above equation.

Exercise C6-2

In this exercise two projections are made using the same economic assumptions but different demographic assumptions. The first projection assumes constant fertility and mortality, while the second assumes a substantial fertility decline over the course of the projection. Specific demographic and economic assumptions are given as part of the projections.

1. Fill in the following table:

	Year 2000	
	Constant Fertility	Declining Fertility
N/POP		
K/N		
GNP/K		
GNP/POP		
C/GNP		
C/POP		

Note the changes in values of the above key indicators associated with the fertility decline. Explain the behavior of GNP/POP in terms of the other three ratios.

2.@ Graph the growth rates of GNP, employment, and capital for the two projections. Explain the differences in GNP growth in the two projections in terms of the differences in the growth of the two factors of production, capital and employed labor.

3. Calculate the ratio of GNP to employed labor, GNP/N, in the initial year, midpoint, and final year of each projection. What factors make this ratio change over the projections? How can labor force growth influence capital growth, even if the "b" population coefficient in the consumption function is zero?

4. What mechanism appears to be primarily responsible for the divergence between the values of per capita GNP at the end of the two projections?

Exercise C6-3

The objective of this exercise is to explore in greater detail the sensitivity of the economic-demographic projections to changes in the parameter values. The suggested procedure for doing this is to enter new parameter values, in response to the queries printed out by the computer, and compare the results with the base runs performed in Exercise C6-2. The demographic assumptions that can be varied include those on fertility, mortality, and the initial age compositions. The economic assumptions that can be varied include those on the returns to scale in the production function, the coefficients in the consumption function, and the employment rate. Each of these economic assumptions warrants some additional comments.

1. Returns-to-Scale

   The sum of the exponents of capital and labor in the production function, u and v, determines the returns to scale. If the proportional increase in output is less than, equal to, or more than a proportional increase in both inputs, then returns to scale are said to be decreasing, constant, or increasing, respectively.

   In Exercise C6-2 the sum of the exponents was 1, meaning constant returns to scale. Try model runs using the same parameters as in Exercise C6-2 with both increasing (u + v greater than 1) and decreasing (u + v less than 1) returns to scale. To change returns to scale, you must respond affirmatively to the computer query "Change Returns to Scale?," and enter the appropriate values.

2. The Coefficients in the Consumption Function

Recall that the consumption function in the model contains a coefficient b that, with positive values, tends to reduce resources otherwise available for investment as population grows faster, ie,

$$I = GNP - C = (1 - a)GNP - b \cdot POP$$

Exercise C6-2 used a given value for b. Try runs with larger and smaller values for b. To detect the sensitivity of the model to changes in b, it will be necessary to keep the initial ratio of consumption to GNP constant. To do this, first calculate the ratio C/GNP for the initial projection year in Exercise C6-2. Select a new value for b and calculate the corresponding value for the a coefficient such that

$$a = \frac{C}{GNP} - b\,\frac{POP}{GNP}$$

where C, GNP, and POP have their values for the initial year. For example, assume the following initial values of the relevant variables from the previous run:

$$\frac{C}{GNP} = 0.85$$

$$\frac{GNP}{POP} = 200$$

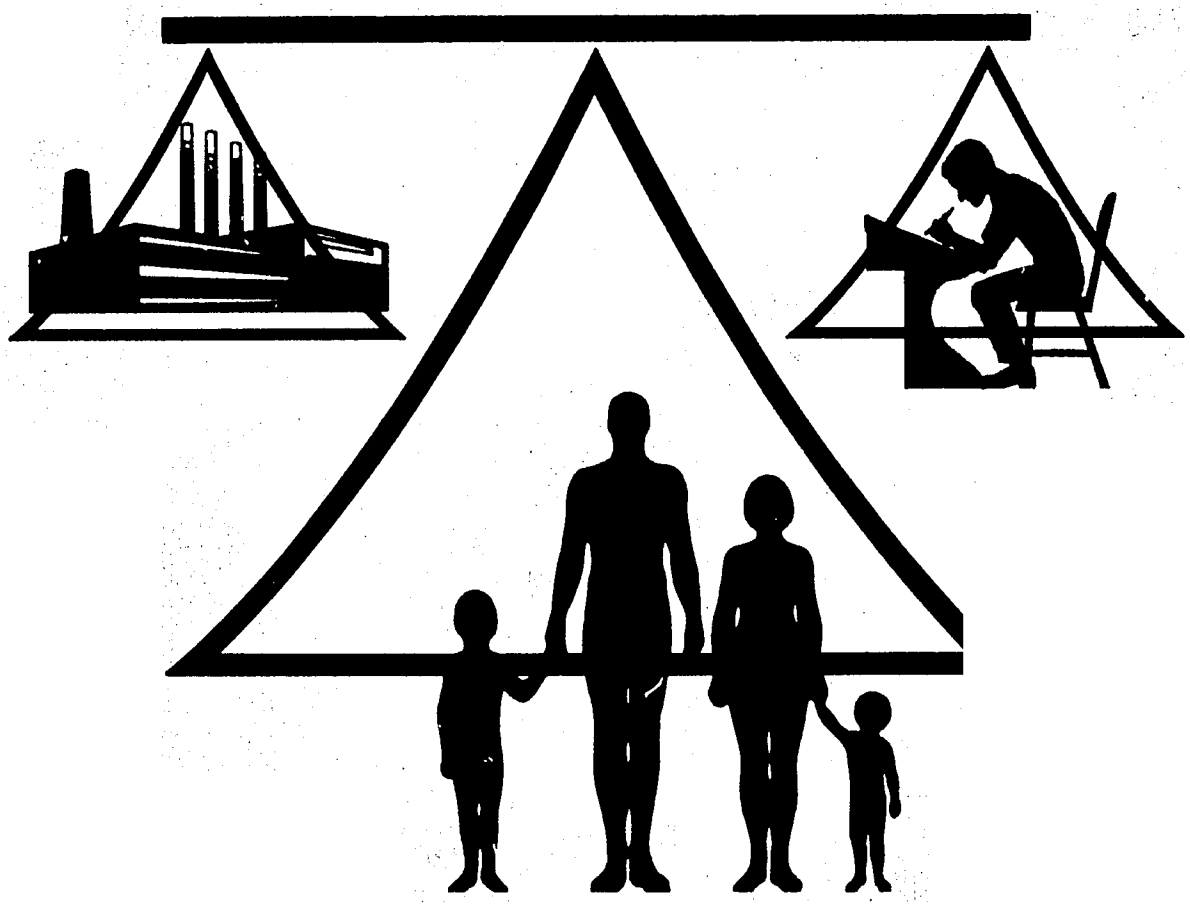
If the new values of b that you wish to try is zero, then the appropriate value of the a coefficient would have to increase from 0.75 to 0.85 in order to keep the initial ratio of consumption to GNP constant.

The Employment Rate

Change the final value of the employment rate used in Exercise C6-2 by responding affirmatively to the appropriate query from the computer. Repeat the questions listed under Exercise C6-2 using the new runs with changed parameter values.

CHAPTER 7

GOVERNMENT EXPENDITURES AND THE IMPLIED TRADEOFFS



GOVERNMENT EXPENDITURES AND THE IMPLIED TRADEOFFS

INTRODUCTION

During any given year, the total goods and services available to an economy are relatively fixed, the amount available depending largely upon the economy's resources and productive capacity. Within limits, however, the mix of goods and services and the uses to which they are put are subject to discretionary changes. For example, the sum of all of the individual household, business, and government decisions in an economy determine how the gross national product is divided between consumption and investment. Some of the implications of changing the split between consumption and investment can be investigated with the model presented in Chapter 6. Such choices always involve some sort of tradeoff, eg, foregoing current consumption in return for higher future production that should result from the higher level of current investment.

Every major decision made by a nation's government involves similar choices and tradeoffs. Thus the government may decide to spend more or less on any of its various programs, eg, direct government investment, education, health, or defense. But given the constraint on the total goods and services available, the decision to increase spending on one program must come either at the expense of other government programs or at the expense of private spending for consumption and investment. The resulting tradeoffs should be gauged in terms of both short and longer run consequences. Program decisions made over a period of years may have a significant impact on investment and the long-run availability of goods and services, and consequently on the total development of the country. For this longer run analysis, demographic factors become increasingly important.

The economic-demographic model presented in Chapter 6 has been modified in this chapter to explore such tradeoffs in more detail. Following a discussion of a new government sector and how it relates to the earlier model, the remainder of the chapter is devoted to a consideration of several tradeoffs involved in the expansion and contraction of government programs, particularly education and government investment programs, and how these tradeoffs are affected by changing demographic conditions.

THE GOVERNMENT SECTOR

Introductio

The public sector encompasses a large number of programs competing for the same resources. Table 7-1 lists the composition of a sample budget for a typical developing country. The model gives explicit treatment to only two programs, education and direct government investment, and aggregates all other expenditures into a general category called "other." This division of the budget is chosen to illustrate the links with the economic-demographic analysis introduced earlier and to exhibit the general nature of major trade-offs. The "other" category includes the whole range of government programs from defense to postal services. The decision to use this three-way split of the government budget was made to illustrate several important elements of projection analysis and does not imply a judgment about the relative importance of any of the categories.

Table 7-1. Plausible government expenditures as a percent of GNP for a developing country.

Categories	Percent of GNP
Education	4.0
Transfers	2.0
Health	1.0
Social overhead capital	3.0
Direct government investment	2.0
Defense	2.0
General	5.0
Total government expenditures	19.0

All taxes are aggregated into a single variable. For most of the exercises, it is assumed that taxes are proportional to the GNP.

To investigate a wider range of assumptions than would be possible with a single specification of the model, four different versions of the government sector are used that are similar except in the determination of two or three variables. For example, in two versions, taxes are assumed proportional to the GNP and total government expenditures are determined by the level of taxes. The sum of the three independently determined components of government spending determines total government spending in the other versions; government spending, in turn, determines the level of taxes.

Total Government Spending and Taxes

For all versions of the model, it is assumed that total government spending, G, must be equal to total tax revenues, TAX. In Versions A and D of this model, total government spending is the sum of the three component programs (ie, education, investment, and other), and taxes are equated to the resulting total:

$$G_t = ED_t + IG_t + OTHER_t \qquad (9a,d)^*$$

$$TAX_t = G_t \qquad (10a, d)$$

where ED, IG, and OTHER are the education, direct government investment, and "other" budgets, respectively.

In the other two versions of the government sector, B and C, taxes are a fixed proportion tx of the GNP, and total government spending is equated to the level of taxes:

$$G_t = TAX_t \qquad (9b,c)$$

$$TAX_t = tx \cdot GNP_t \qquad (10b,c)$$

Component Spending Programs

Versions A and D: Government Spending Determines Taxes. When tax revenues are adjusted to meet the desired level of government spending, as in Versions A and D, then the budget components are determined independently of the size of the total budget. It is assumed that the direct government investment and "other" budgets are determined as a fixed proportion of total GNP. The education budget can be calculated either as a proportion of the GNP (Version A) or as the cost of achieving specific education goals:

$$ED_t = e \cdot GNP_t \qquad (11a)$$

or

ED_t = cost of achieving pre-specified enrollment and advancement targets, as described in Chapter 4 (11b,c,d)

$$IG_t = fa \cdot GNP_t \qquad (12a,d)$$

The equation numbers given here are the same as those in the summary at the end of this subchapter. The lower case letters (a, b, c, and d) given with the government sector equation numbers refer to the version of the government sector (A through D) to which the equations apply.

$$OTHER_t = ga \cdot GNP_t \qquad (13a,d)$$

where e, fa, and ga are respectively the proportions of GNP devoted to education, direct government investment, and other government expenditures.

When using the education model for planning, as is also done for Versions B and C, education targets are determined by setting specific enrollment and advancement rates for each level of schooling, ie, primary, secondary, and tertiary. The cost of achieving a particular education goal is a function of the cost per student, the enrollment and advancement rates, and the size of the school-age cohorts.

Only the primary enrollment rate is specified directly. The secondary and tertiary enrollment rates are determined by the previous levels of enrollment, advancement rates, and by the age-specific mortality rates, as explained in Chapter 4. Target education rates are established for the initial and final years of the projection, eg, the primary enrollment ratio increasing from 50 percent in 1970 to 80 percent in 2000. Rates for intermediate years are determined by interpolation between initial and final rates.

The principal objectives of tradeoff analysis for education are to determine the impact of different education goals on other public and private expenditures and to investigate the role that demographic conditions play in determining that impact.

Versions B and C: Taxes Determine Government Spending. When total government spending is constrained to equal tax revenues, as in Versions B and C, then either the government investment budget or the "other" budget is determined as a percent of total government spending. If government investment is assumed proportional to the total government budget, then the "other" budget is the residual that remains after first deducting investment and education expenditures from the total budget. (The education budget is determined by the cost of attaining pre-specified goals, as is discussed above.) Then

$$IG_t = fb \cdot G_t \qquad (12b)$$

$$OTHER_t = G_t - ED_t - IG_t \qquad (13b)$$

If the "other" budget is proportional to the total government budget, then government investment is the residual remaining after deducting the education and "other" expenditures:

$$IG_t = G_t - OTHER_t - ED_t \qquad (12c)$$

$$OTHER_t = gb \cdot G_t \qquad (13c)$$

Modification of the Economic Model

With the inclusion of a government sector, some of the relationships used in the economic model of Chapter 6 must be modified. In particular, the equations determining consumption and investment must be modified to take into account the share of these expenditures determined in the public sector. The first four equations of the model, determining GNP, the labor force, employment, and capital, are not changed.

The "consumption" of Chapter 6 includes *both private and public* sector consumption. In the modified model of this chapter, however, "consumption" refers *only to private* consumption. It thus becomes dependent on the size of total *disposable* income, YD, available to the private sector, instead of the GNP. Thus, consumption is

$$C_t = a \cdot YD_t + b \cdot POP_t \quad . \tag{5}$$

Disposable income is the difference between GNP and taxes, TAX. That is,

$$YD_t = GNP_t - TAX_t \quad . \tag{6}$$

Total net investment, I, is the sum of private net investment, IP, and direct government (net) investment, IG:

$$I_t = IP_t + IG_t \quad . \tag{7}$$

Like private consumption, net private investment is now dependent upon disposable income instead of GNP:

$$IP_t = YD_t - C_t \quad . \tag{8}$$

Summary of the Modified Economic-Demographic Projection Model

I. Demographic Model
As described in Chapter 2.

II. Economic Model

1. $GNP_t = z(1 + q)^t \cdot K^u_{t-1} \cdot N$

where GNP measures total output, K is capital, and N is the size of the employed labor force.

$$2.\quad L_t = \sum_{i=4}^{13} \left(lfprm_i \cdot POP_{m,i,t} + lfprf_i \cdot POP_{f,i,t} \right)$$

where L is the total labor force, and $POP_{m,i}$ and $POP_{f,i}$ are the respective male and female population i^{th} age cohorts.

$$3.\quad N_t = n \cdot L_t$$

$$4.\quad K_t = K_{t-1} + I_t$$

where I is the value of net investment.

$$5.\quad C_t = a \cdot YD_t + b \cdot POP_t$$

where C is the value of total private consumption, YD is total disposable income available to the private sector, and POP is the size of the total population.

$$6.\quad YD_t = GNP_t - TAX_t$$

where TAX is the total of government tax receipts, as determined in the government sector of the model.

$$7.\quad I_t = IP_t + IG_t \quad ,$$

where IP is net private investment and IG is net government investment. Net government investment is determined in the government sector.

$$8.\quad IP_t = YD_t - C_t \quad .$$

III. Government Sector

Version A. Government expenditures are the sum of the three budgets: education investment, and "other." Each program is determined as a proportion of the GNP. Taxes equal government expenditure

$$9a.\quad G_t = ED_t + IG_t + OTHER_t$$

where G is total government expenditures, and ED, IG, and OTHER are the respective government budgets for education, investment, and all other.

$$10a.\quad TAX_t = G_t$$

$$11a.\quad ED_t = e \cdot GNP_t$$

12a. $IG_t = fa \cdot GNP_t$

13a. $OTHER_t = ga \cdot GN$

Version B. Government expenditures are determined by taxes. The education budget is the cost of meeting pre-specified enrollment and advancement targets. Government investment is proportional to total government expenditures. Other government expenditures are a residual component o the budget. Taxes are proportional to GNP.

9b. $G_t = TAX_t$

10b. $TAX_t = tx \cdot GNP_t$

11b. ED_t is given from enroll... described in Chapter 4.

12b. $IG_t = fb \cdot G_t$

13b. $OTHER_t = G_t - ED_t - IG$

Version C. The same as Version B except that "other" government expenditures are proportional to the total government expenditures and government investment is a residual component of the budget.

9c. $G_t = TAX_t$

10c. $TAX_t = tx \cdot GNP_t$

11c. ED_t is given from enrollment and advancement targets, as described in Chapter 4.

12c. $IG_t = G_t - OTHER_t - ED_t$

13c. $OTHER_t = gb \cdot G_t$

Version D. The same as Version A except that the education budget is the cost of meeting pre-specified enrollment and advancement targets.

9d. $G_t = ED_t + IG_t + OTHER_t$

10d. $TAX_t = G_t$

11d. ED_t is given from enrollment and advancement targets, as described in Chapter 4.

12d. $IG_t = fa \cdot GNP_t$

13d. $OTHER_t = ga \cdot GNP_t$

TRADEOFFS

Decisions by planners and government policy makers generate streams of costs and benefits over time for the direct object of the expenditure and for complementary and competing programs as well. Presumably the final choice of projects and budget levels is determined by a complex set of factors, including political and welfare considerations. But whatever these considerations may be, the decisions should consider how a given program interacts within the total budget and with the economy as a whole, eg, the tradeoffs involved in increasing or decreasing a program's size.

The approach used here is to examine sample budgetary configurations for possible tradeoffs, breaking the analysis into steps of increasing complexity. At first, all but one or two assumptions are held constant in order to isolate certain effects. Additional factors are then altered as the simpler interactions are understood.

The reader is asked to assume the position of a planner who must determine the level of government expenditures on education, investment, and the total available for all other government projects. He makes these decisions within the context of economic-demographic projections generated by the model outlined above.

Public-Private Tradeoffs

The first type of tradeoff considered is that involved in the decision to change the split between public and private spending. For example, assume that increased budgets for one or several component programs require an increase in total government expenditures and, using Version A of the government sector, an increase in taxes. The cost of increasing the budget is, in this case, the private spending foregone due to the increased taxes. Much of the reduced private expenditure will fall on consumption, but private investment will be lowered also. The policy maker should consider whether the benefits from increasing the government programs are sufficient to offset the decreased private consumption and investment. This assessment should include an evaluation of future as well as current impacts.

Before proceeding further, it should be noted that of the three categories in the government budget in the model, only government investment has a direct impact on the rest of the economy. Government investment

is assumed to produce the same changes in capital as private investment. In contrast, no impact is recorded from education and the various components of "other" government expenditures. This assumption has been adopted at the expense of realism to simplify the analysis. Of course, education, health care, and many other government expenditures do increase labor productivity and output, in addition to having other beneficial effects.

The specific uses of the additional tax revenue have different impacts on the economy. For instance, if most of the new tax revenue goes into government investment, then the growth of total investment and capital will be accelerated. A tax increase of 1 percent of GNP might diminish private investment by about one-fifth of that amount, but total investment would rise if government investment takes more than 20 percent of the new tax revenues. With the more rapidly growing capital, future incomes and budgets would tend to grow faster. But this might be at the expense of important current needs that would otherwise have been satisfied either from other government expenditures (eg, education, health, transfers) or from higher private consumption.

In the next exercise, these public-private tradeoffs are investigated by increasing the total government budget, holding the composition of government expenditures constant, and then seeing how the private sector responds. Remember that these responses and tradeoffs also change over time, especially as changing demographic conditions come into play.

Exercise C7-1. Public-Private Tradeoffs

In the exercises of this chapter, the basic economic and demographic assumptions are generally the same as those used in earlier chapters, except that some of the economic parameters described in Chapter 6 have been modified to take into account the addition of the government sector in this chapter. The most important assumptions used in the projections are given as a part of each projection.

This exercise uses Version A of the government sector, with total government expenditures determined by summing the budget components and tax revenues equated with the resulting total budget. Run a projection, specifying *as a proportion of total GNP* the desired expenditure levels for education, government investment, and "other." Table 7-1 may be helpful in choosing initial values for these proportions. The demographic assumptions are the same as those used in the first projection of Exercise C6-1. The economic assumptions have been adjusted to take into account the presence of the new government sector. Run a second projection, with the ratio of each component budget to GNP increased by 50 percent.

1. Without looking at the projections, what should happen to the tax rates over time?
2.@ For the two projections, plot private consumption, private investment, and total investment.
3. When total government spending increases, what happens to total private spending? To private consumption?
4. Since the government budget is funded by taxes taken from individual incomes, does this mean that private consumption must fall by the full amount of the tax increase?
5. What does this result mean for private investment?
6. What happened to total investment?
7. How does the change in total investment affect private consumption and government expenditures in future years of the projection?
8. How might the levels of GNP, GNP per capita, consumption, and capital differ if the government were not included in the model? How could you verify your answer with computer projections?
9. How would you describe the costs of the increased government expenditures?
10. If there were a 25 percent increase in fertility rates, how might your answers to the preceding questions be altered?

TRADEOFFS WITHIN THE GOVERNMENT BUDGET

Tradeoff Between the Education and "Other" Budgets

In this section, the impact on "other" government expenditures of changing the education targets and the resulting education budget is considered. Version B of the government sector is used, which means that changing the education targets will have no impact on government investment, the total government budget, private spending, or the growth of the GNP. Whatever increase might be required for the education budget is taken directly from the "other" government budget.

Education targets for the future are determined in terms of enrollment and advancement rates. The choice of these parameters determines education resource costs in terms of teacher salaries, new teacher training, school room construction, and maintenance. The unit costs of teachers, teacher training, etc, are taken as given. These costs combine to provide the budget each year required to meet the specified targets. A first step toward understanding the tradeoffs involved in changing education targets is to investigate how the changes might alter the total funds available to other government programs. The impact, of course, is quite sensitive to the assumptions made about future demographic conditions.

Figure 7-1 illustrates a possible tradeoff between education and "other' government budget expenditures, given a fixed tax rate on GNP and a fixed percent of the budget spent on government investment. The choice of present and future education goals requires specific expenditures commensurate with the goals. Higher goals leave less of the total budget for "other" projects. A decision to achieve a specific goal, say, to increase primary enrollment rates from 50 percent in 1970 to 80 percent in the year 2000, will alter expenditures on "other" projects in those intermediate time periods.

The tradeoff through time between education and "other" depends on many different factors, economic and demographic. For example, the faster the growth of the total government budget (perhaps the result of faster growth of the GNP), the smaller is the proportion of the budget required for education and the larger the proportion of the budget available for "other." Even though a dollar increase in education expenditures might still mean a dollar decrease in "other" expenditures, the significance of that dollar decrease could be very different.

Also, the change in the education budget is very sensitive to changing fertility and infant-child mortality. High fertility rates imply high rates of growth of the school-age population and a higher cost of meeting any given

enrollment rate and advancement rate goals. Improving infant-child mortality is beneficial as an end in itself, but does have the impact of increasing the cost of achieving these goals. Declining fertility tends to lower these costs.

Thus, an investigation of the relative and absolute costs of achieving specific education targets requires consideration of many factors that lie outside the education system.

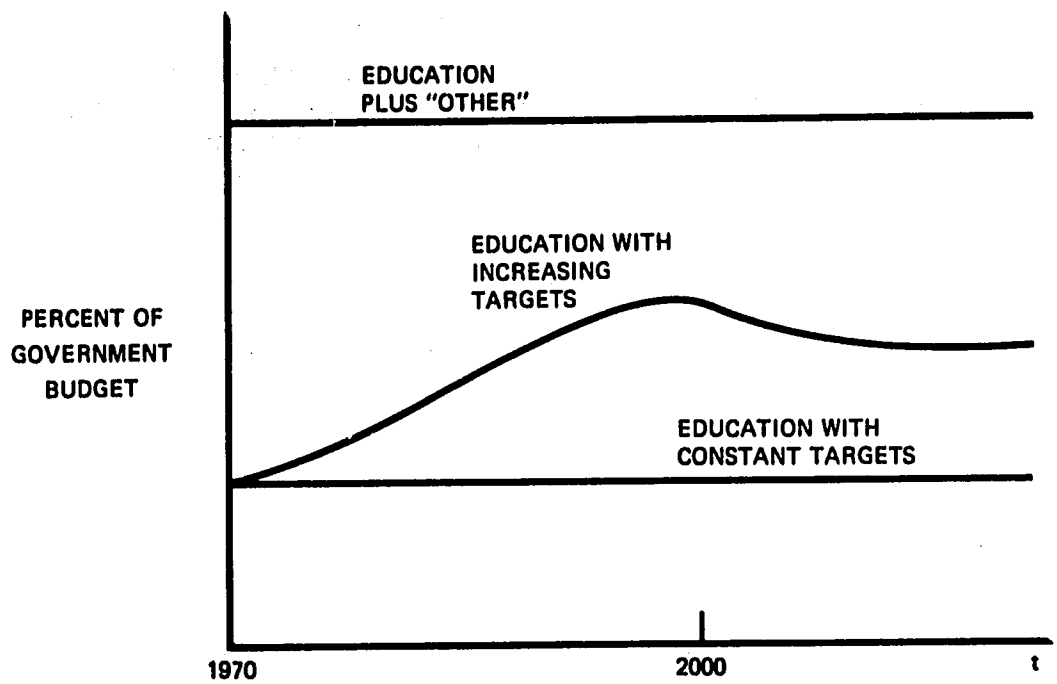


Figure 7-1. Effect of increasing education enrollment targets on the education and "other" budgets, assuming constant fertility and mortality.

Review Questions

1. In Figure 7-1 it is assumed, as a line of reference, that both education and "other" are constant proportions of the total budget with constant education targets and constant fertility and mortality. Increasing the education enrollment targets between 1970 and 2000 causes the share of the budget taken by education to first rise and then to decline to a new level somewhat higher than the 1970 share. What might account for such a pattern through time? (Hint: Recall that not all education costs respond in the same manner to changing school enrollments.)

2.@ Review Figures 4-2 and 4-3, which illustrate the impacts of changing education targets and demographic conditions on teacher requirements. On the basis of these graphs, modify Figure 7-1 to show the effect that a similar decline in fertility might have on the tradeoff between the education and "other" budgets.

Exercise C7-2. Tradeoffs Between Education and "Other"

This exercise makes extensive use of the education model described in Chapter 4. The discussion and exercises in that chapter should therefore be reviewed if they are not fresh in the reader's mind. The projections use Version B of the government sector. (Note that in Version B government investment is assumed proportional to total government expenditures.)

This exercise uses two sets of projections, the first assuming that fertility remains constant and the second assuming that fertility declines. For each set of fertility assumptions, make three projections using different assumptions about increasing the primary enrollment ratio. (The first projection of each set should assume a constant enrollment ratio.) The basic demographic, economic, and government sector assumptions are given as part of the projections.

First, make three projections using the constant-fertility assumption.

1. Compare the results with those in Exercise C7-1.

2.@ Graph the total government budget, the "other" budget, and the education budget for each of the three projections. Plot only the values for every tenth year.

3. What happens to the portion of the budget remaining for "other" when the educational targets are raised?

What impact does changing the education budget have on the growth of GNP? Why?

What types of government projects might have to be sacrificed if educational enrollment rates were raised? If these higher enrollment rates are to be maintained, what other solutions are possible besides lowering "other" expenditures?

Repeat the projections, making the same assumptions about primary enrollment ratios but choosing the declining-fertility assumption. Repeat questions 1 through 3 and compare your answers with those given for the constant-fertility projections.

Tradeoffs—Government Investment, "Other," and Education

Neither the education budget nor the "other" government budget has a direct impact on the growth of investment and the GNP, given the assumptions of Version B of the government sector. In fact, different government programs may interact directly or indirectly with the economy in such a way as to affect a planner's choices (eg, by changing the rate of growth of GNP). With the simplified government sector used in this chapter, the only component of the government budget to interact directly with the economy is direct government investment.

Increasing the budget for government investment might have any of several direct effects. First, the direct effect of increasing the rate of government investment is to increase the rate of total net investment and to thereby accelerate the growth of GNP. Second, increasing the government investment budget might increase total government spending, with an associated reduction in private consumption and investment (as in Versions A and D of the government sector). Third, it might reduce the budgets of other government programs

Version B of the government sector can be used to show the impact of increasing government investment at the expense of "other" government expenditures. Version C of the government sector can be used to investigate the impact of changing the mix between the government investment and education budgets.

Exercise C7-3. Tradeoffs Between Government Investment and "Other"

This exercise uses Version B of the government sector. Using the same educational targets and government budget of one of the projections of Exercise C7-2, make two additional constant-fertility projections, each using a different ratio of government investment to total government spending. Be careful that ED and IG together do not spend more than the total budget.

1.@ Plot a graph of the total government budget, the education budget, and the budget for "other" expenditures for the three educational targets. Do this for each of the government investment assumptions. Compare these results with those of Exercise C7-2. How do the results of the several projections differ?

2. Explain the differences described in question 1.

Repeat this exercise using the declining-fertility option.

Exercise C7-4. Tradeoffs Between Education and Government Investment

Repeat Exercise C7-2, using Version C of the government sector and investigating the tradeoffs between education and government investment.

Exercise C7-5

This exercise uses Version D of the government sector. From the tradeoff information gained in the earlier exercises, choose a total budget with final target levels of expenditure for education, government investment, and "other" consistent with your particular planning goals. Indicate how these plans would be changed if the fertility or mortality rates were expected to change.

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