Part I

Introduction

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Demography

1.1 Demography

The word demography is derived from the Greek words "demos" meaning people, and "graphia" meaning the science of. Demography is the study of human populations, and it investigates such aspects as size, structure, distribution over space, socioeconomic characteristics, households and families, migration, labor force, and vital processes of populations. (For further elaboration see the Encyclopedia of the Social and Behavioral Sciences (2001).)

Researchers from many different backgrounds identify themselves as demographers. An attempt to synthesize the perspectives of these different disciplines into a definition of demography could be summed up as a science that analyzes populations based on the methods and techniques of mathematics and statistics, and on theories from the social and biological sciences.

The focal points of demography are changes in size, growth rates, and the composition of populations. The discipline is not limited to examining aggregated processes or individual-level behavior, but it also looks at interactions between the micro and macro level of analysis.

In order to accurately explain population phenomena, demographers usually follow the principle of separating demographic variables into parts that explain the different components of the phenomena. This aids in specifically analyzing the effects that each component has on the whole dynamic. The present book encompasses the study of how to properly separate demographic variables' changes over time. This methodology is known as decomposition technique and corresponds to the field of demography generally referred to as formal demography.

Like most other sciences, demography may be defined narrowly or broadly. In the narrowest sense, formal demography constitutes the core of demography.

Demographic measures are described by mathematical formulas. The mathematics used in the formulas and the methodology to explain the relations between different demographic

measures is the essential part of formal demography (for more details see Keyfitz (1985)). A vital part of formal demography is the development of new methodologies and applications of mathematics in demographic analysis.

Formal demography provides us with several different methods that facilitate comparisons of populations over time. One of these techniques is the decomposition method, which will be explained here in detail.

1.2 Decomposition Techniques

Rates, indices and average ages of population are demographic variables which are used as convenient summary measures of mortality, fertility, migration, and other population phenomena. For example, Schoen (1970) points out that a mortality measure or index should have four properties. It should be unique, respect the proportional difference between the corresponding elements in the age-specific schedules, reflect the nature of the underlying mortality function and not be affected by confounding factors. Nevertheless, these desirable properties are seldom fully fulfilled by an index. On the one hand, indices have the advantage of being easily interpreted, but on the other hand, they usually suffer from the disadvantage of being single-figured. In other words, all the demographic phenomena has to be learned from this single value. This ambiguity becomes more evident when comparing measures over time or by population, sex, age or other categories.

Confounding influences on population data may not be solely due to age, but also to other compositional traits such as sex, race-ethnicity, urban-rural residence, marital status, socioeconomic status, and many other characteristics. Populations often differ greatly in these traits and any given population can undergo important compositional changes over time.

We examine some questions on changes which might be affected by confounding factors: Why is the Mexican crude death rate declining over time? Is it due to a decline in mortality or to a change in the population's age structure? Why are the crude birth rates in Denmark, the Netherlands and Sweden declining? Is it due to a decline in fertility among married and unmarried, or to the fact that compositions from both groups are changing over time? We could also examine the overall life expectancy of selected European countries. The question then would be whether the change over time in life expectancy is because of a decline (or increase) in life expectancy in each country or because of change over time in the population composition of the respective countries.

In order to obtain summary measures which take account of compositional effects (age, marital status, nationality or other characteristics), demographers have devised a number of techniques. In this book, we focus on how decomposition methods can be used to analyze the problems of confounding compositional effects.

In general, to decompose means to separate something into its constituent parts or elements or into simpler compounds. The decomposition methods used in demography also follow this separation principle by dividing demographic variables into specific components.

Decomposition methods are used when comparing demographic variables that belong to different populations, or when comparing variables of the same population over time. To answer our research questions, here, we mainly apply decomposition methods to study changes in demographic variables over time.

1.3 Research Question

This book focuses on a comparison of the different decomposition methods used in demography. The main purpose of this research is to answer the following question:

Which are the components of the change over time of demographic variables?

The answer to this question can be found in Part III, where a decomposition method presented by Vaupel (1992) is further developed. This method separates the changes over time of demographic variables into two components and it is simply referred in the rest of the book as the *direct versus compositional decomposition*. This decomposition method has similarities to previous techniques of separating changes over time. The most relevant of these techniques used for studying demographic variables are reviewed in Part II. Taking the similarities between existing methods in this field and direct vs. compositional decomposition into account led to new queries about decomposition methods, which can be summed up as follows:

What are the advantages and disadvantages of direct vs. compositional decomposition relative to the previous methods?

The answer to this question is found in Part IV wherein direct vs. compositional decomposition and the previous methods are compared.

The following is an overview of the parts of the book.

1.4 Organization of the Book

The book is divided into four parts:

- Part I consists of two chapters, including the present *Introduction*. Chapter 1 provides an orientation to this book as well as to the field of study that utilizes decomposition methods. Chapter 2 describes the special notation used throughout the book. The mathematical calculations and proofs used throughout the text are not difficult and do not require any mathematical knowledge beyond elementary arithmetic and calculus.

- Part II, on *Decomposition Methods*, is a literature review of existing decomposition methods, and it is divided into three chapters. The first chapter, Chapter 3 presents some of the early developments in decomposition methods. Chapter 4 goes on to describe contributions to the methodological development of particular demographic fields: mortality, fertility and population growth. Chapter 5 lists alternative decomposition methods used in demography.

- Part III, which presents a method for *Decomposing Change Into Direct Versus Compositional Components*, is the main part of this book and includes four chapters. Chapter 6 presents a decomposition method for the change over time of demographic functions developed by Vaupel (1992). Also this chapter includes applications presented by Vaupel and Canudas Romo (2002) and decompositions suggested by Vaupel and Canudas Romo (2003). The remaining three chapters include some of this author's contributions to this area by extending Vaupel's method. Chapter 7 outlines an age, category and cause of death decomposition. This chapter shows how to calculate the contribution of change

in any given age group, category or cause of death, to the total change of demographic measures. Chapter 8, on *Multidimensional Decompositions,* includes the decomposition of change over time for a demographic variable when numerous compositional components are present. The last chapter in Part III, *Estimation of Derivatives in Demography*, is concerned with the estimation procedures of derivatives and intensities over time for demographic functions involved in the analysis.

- Part IV, *Evaluation of the Decomposition Methods*, is devoted to comparing direct vs. compositional decomposition presented in Part III with the previous decomposition methods presented in the preceding literature review provided in Part II. This part of the book contains two chapters. The former, Chapter 10, is divided into five main sections corresponding to sections and chapters in Part II. The first section contrasts direct vs. compositional decomposition with earlier methods. Next there is an examination of the decompositions in life expectancy, crude birth rate and population growth association with direct vs. compositional decomposition. Finally, some relationships between the alternative methods and direct vs. compositional decomposition are shown. Chapter 11 comprising general conclusions brings this book to a close. The sections of this chapter consist of an introduction, a section on desired properties of decomposition methods and concluding remarks. This part of the book concludes the project by showing how and when direct vs. compositional decomposition takes precedence.