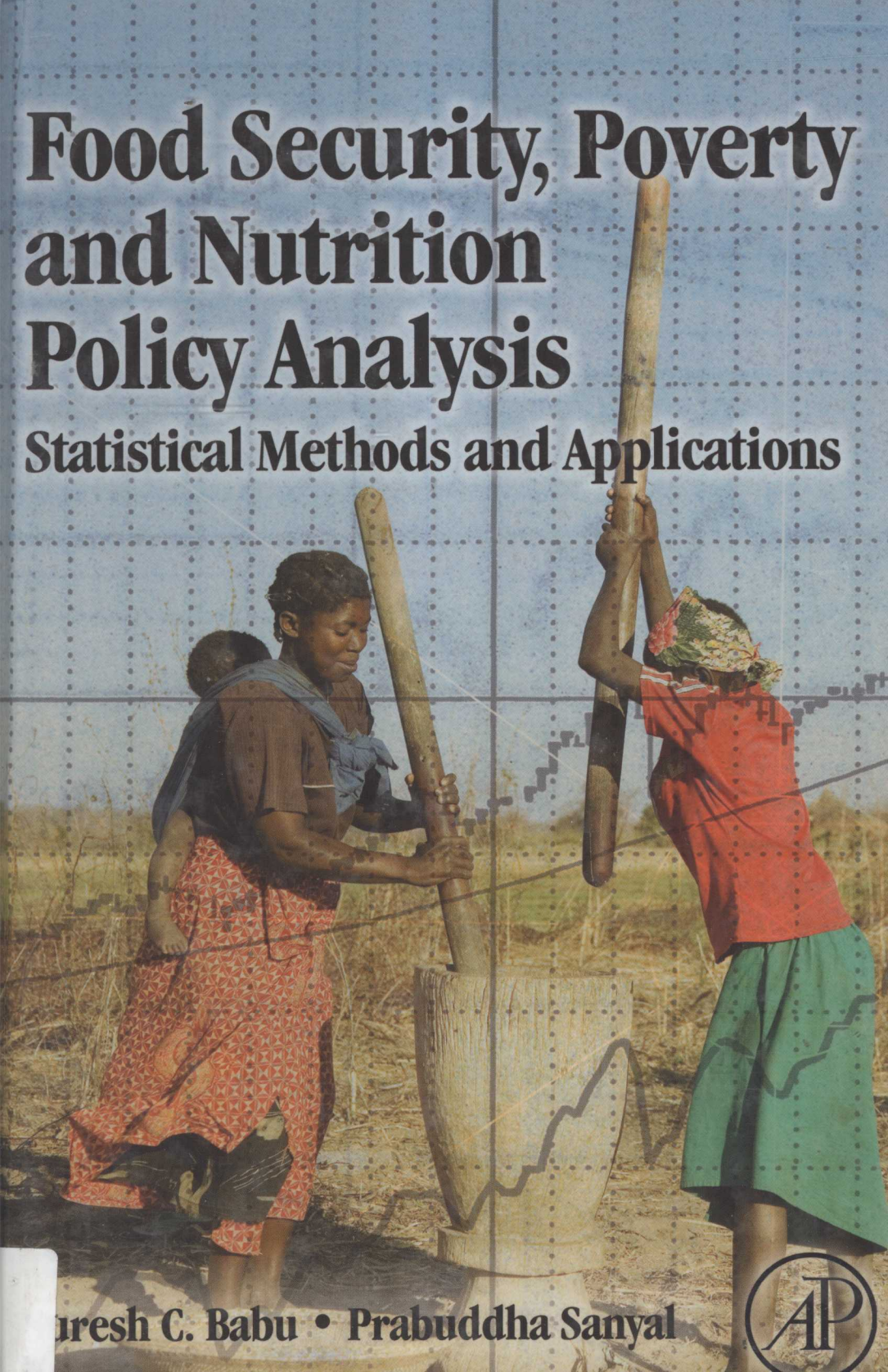
Food Security, Poverty and Nutrition Policy Analysis

Statistical Methods and Applications



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Statistical Methods and Applications

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Food Security, Poverty, and Nutrition Policy Analysis

Statistical Methods and Applications

To

Per Pinstrup-Andersen

Humanist, Food & Nutrition Economist and Teacher

Food & Nutrition Economist par Excellence

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Preface

This book has its conceptual origin from the lecture materials of the training courses taught by one of the authors in the early nineties. It was during this period that in several developing nations, particularly in Africa, even when the signs of widespread hunger and abject poverty were visible, policy makers did not act for want of 'empirical evidence'. Some policy makers even dismissed the severity of the problem saying that the hunger reports prepared by government officials were not rigorous enough to take them seriously. Some decision makers entirely rejected the reports prepared by the officials, stating that the analysis of data was 'not statistically sound' to draw reliable inference and undertake the desirable public actions. The final result was inaction on the part of the policy makers. Little has changed since then as evidenced by the continuing food crises in several countries. Generating empirical evidence on causal factors and severity of food insecurity and poverty problems becomes more urgent also in the context of the recent sharp increases in global food prices.

The capacity to collect, process and analyze data on food security, nutrition and poverty problems continues to remain low in many developing countries. While students are trained adequately in their individual fields of specialization, such as nutrition, economics, sociology, political science, international development, anthropology and geography, they are often ill prepared for the task of policy analysts in the governments, academic and research institutions, civil society organizations and the private sector. Developing applied policy analysis skills requires a combination of several related abilities in statistical data analysis, computer literacy and using the results for developing policy alternatives. In addition, an understanding of issues, constraints and challenges facing policy makers on particular hunger, malnutrition and poverty problems is critical.

This book is largely motivated by and based on three decades of food and nutrition policy research at the International Food Policy Research Institute. In the mid-nineties, the data based statistical methods were combined with selected case studies from IFPRI research on food and nutrition security issues to form a training manual. It was well received among the training institutions and university departments teaching courses on food security and nutrition policy analysis both in the North and in the South. Selected contents of this manual were taught by one of the authors over the years at various institutions in many parts of the world including University of Maryland, University of Sweden, University of Hohenheim, Tufts University, University of Malawi, University of Zimbabwe, Indian Agricultural Research Institute, Andhra Pradesh Agricultural

University, Eduardo Mondlane University, Ghana University of Development Studies and Lamolina University.

This book, a substantially revised version of the manual, attempts to impart the combined skills of statistical data analysis, computer literacy and using the results for developing policy alternatives through a series of statistical methods applied to real world food insecurity, malnutrition and poverty problems. It bases its approach of combining case studies with data based analysis for teaching policy applications of statistical methods from several training courses and class lectures taught in the last fifteen years. Thus, this version has the benefit of the feedback and comments from the users of the earlier version of the manual and the participants of the above training courses. It contains new sections on some advanced statistical methods, including poverty analysis and linear programming for solving diet problems. It has been prepared to cover a semester long course of fifteen weeks.

The book is primarily addressed to students with a bachelor degree who have familiarity with food security, nutrition and poverty issues and who have taken a beginners' course in statistics. It is ideally suited for first year postgraduate courses in food sciences, nutrition, agriculture, development studies, economics and international development. The book is self-contained with its downloadable dataset, statistical appendices, computer programs and interpretation of the results for policy applications. It could be used as course material in face-to-face and distance learning programs.

We hope that the book will be useful in developing a new generation of policy analysts who are well equipped to address the real world problems of poverty, hunger and malnutrition, whose reports will not be rejected for want of empirical evidence and will result in swift public and private action.

Introduction

The nature and scope of food security, poverty and nutrition policy analysis

Problems related to increasing food availability, feeding the population, improving their nutritional status and reducing poverty levels continue to confront decision makers in many developing and developed countries. Program managers and policy makers who constantly deal with design, implementation, monitoring and evaluation of food security, nutrition and poverty related interventions have to make best decisions from a wide range of program and policy options. Information for making such policy and program decisions must be based on sound data-based analysis. Such analysis should be founded on statistical theory that provides an inferential basis for evaluating, refining and, sometimes, rejecting the existing policy and program interventions.

This book deals with the application of statistical methods for analysis of food security, poverty and nutrition policy and program options. A range of analytical tools is considered that could be used for analyzing various technological, institutional and policy options and for developing policy and program interventions by making inferences from household level socioeconomic data.

The objective of policy analysis is to identify, analyze and recommend policy options and strategies that would achieve the specific goals of policy makers (Dunn, 1994). Issues related to increasing food security, reducing malnutrition and alleviating poverty are high on the global development policy agenda as evidenced by recent unprecedented increases in food prices, resultant unrest in several developing countries and a series of international summits convened to mitigate the effects of food price increase (UN Summit, 2008). This book addresses a wide range of policy and program options typically designed and implemented by government agencies, non-governmental organizations and communities to address the development challenges such as hunger, poverty and malnutrition faced by households and communities.

Such policy and program options, for example, aim at increasing the availability of food, increasing the household entitlement, improving the efficiency of food distribution programs, enhancing the market availability for selling and buying food commodities, reducing malnutrition through the school feeding and nutrition programs, increasing technological options through introduction of high yielding varieties of seeds that farming communities in rural areas could grow to increase income, investing in technological advancements, implementing land reforms and distribution of land to poor households, increasing the

education of mothers, improving child-care and promoting changes in consumption patterns and so on. Using such real world policy options and interventions as case studies, the chapters of this book attempt to show how using the analysis of socioeconomic datasets can help in the development of policy and program interventions. The chapters also introduce various approaches to the collection of data, processing of collected data and generation of various socioeconomic variables from the existing datasets. They also demonstrate applications of analysis of the relationship between causal policy variables and welfare indicators that reflect household and individual food security, nutrition and poverty.

Why should a book that teaches statistical methods for analyzing socio-economic data for generating policy and program options be important?

The goal of the decision maker is to select the best option for intervention from a set of choices that are politically feasible and economically viable. Yet making such decisions requires a full understanding of the intended and unintended consequences of the proposed interventions. While the need for rigorous analysis – through assessment of the existing situation – is largely recognized by the policy decision makers before taking necessary action, the needed capacity for undertaking such analysis is grossly lacking in many countries. Hence much of the policy and program decisions related to food security, poverty and nutrition continue to be made under the veil of ignorance.

Improved capacity for food security, poverty and nutrition policy analysis is essential for achieving the Millennium Development Goals (MDG) (UN, 2005). At the global level, the major Millennium Development Goal of 'reducing hunger, poverty and malnutrition by half by the year 2015' remains unachievable in many parts of the world. It has been recognized that one of the major constraints in attaining the MDGs related to hunger and malnutrition is the lack of capacity for scaling up of food and nutrition interventions (World Bank, 2006). Scaling up requires capacity for monitoring, evaluation and adoption of successful food and nutrition programs. Such capacity is severely lacking at the global, national and local levels.

A good conceptual understanding of the issues related to food and nutrition, economic concepts, statistical techniques and policy applications with case studies will help in understanding how quantitative analysis could be used for designing program and policy interventions. Students who take up jobs that involve designing, implementing, monitoring and evaluation of development programs are often ill prepared to undertake these tasks. Based on one statistical course students take in the undergraduate program and with their little exposure to food and nutrition issues, for example, they are expected to perform the role of policy and program analysts. Even if they are well trained in the individual disciplines such as food and nutrition, statistics, monitoring and evaluation, or policy analysis, they are often not adequately trained to combine these disciplines to address real world food and nutrition challenges.

A book that brings together concepts and issues in food security, nutrition and poverty policy analysis in a self-learning mode can serve thousands of policy

analysts, program managers and prospective students dealing with designing, implementing, monitoring and evaluation of food security, nutrition and poverty reduction programs.

Objectives of the book

The purpose of this book is to provide readers with skills for specifying and using statistical tools that may be appropriate for analyzing socioeconomic data and enable them to develop various policy and program alternatives based on the inferences of data analysis.

The chapters of the book introduce a wide range of analytical methods through the following approaches:

- review a broad set of studies that apply various statistical techniques and bring out inferences for policy applications
- demonstrate the application of the statistical tools using real world datasets for policy analysis
- use the results of the analysis for deriving policy implications that provide useful learning for policy analysts in designing policy and program options.

Organization of the book

The fifteen chapters of the book are organized into three broad sections. The first section deals with food security policy analysis, the second section addresses nutrition policy analysis and the third section covers the special and advanced topics on food and nutrition policy analysis including measurement and determinants of poverty. This section also provides an introduction to modeling with linear programming methods.

To show the interconnectedness of the issues addressed by the chapters of this book to broad development goals, Figure I.1 identifies the placement of the chapters as they relate to specific policy challenges. The broad conceptual approach used throughout this book, explained later in greater detail, is also depicted in Figure I.1.

The conceptual framework outlined in Figure I.1 is a tool for analyzing the impacts of policies and programs on food and nutrition security outcomes at the household level. It links various policies at the macro, meso (markets) and micro (household) levels (Metz, 2000). Economic changes induced by various macro policies influence markets which, in turn, affect food security at the household level. Food entitlements in terms of availability and access to food at the household level are affected by various policy interventions. Both macroeconomic (exchange rate, fiscal and monetary policies) and sector-specific policies (agriculture, health, education and other social services) affect markets, infrastructure and institutions. The markets can be subclassified into food markets and other markets for essential consumer goods, production inputs and credit.

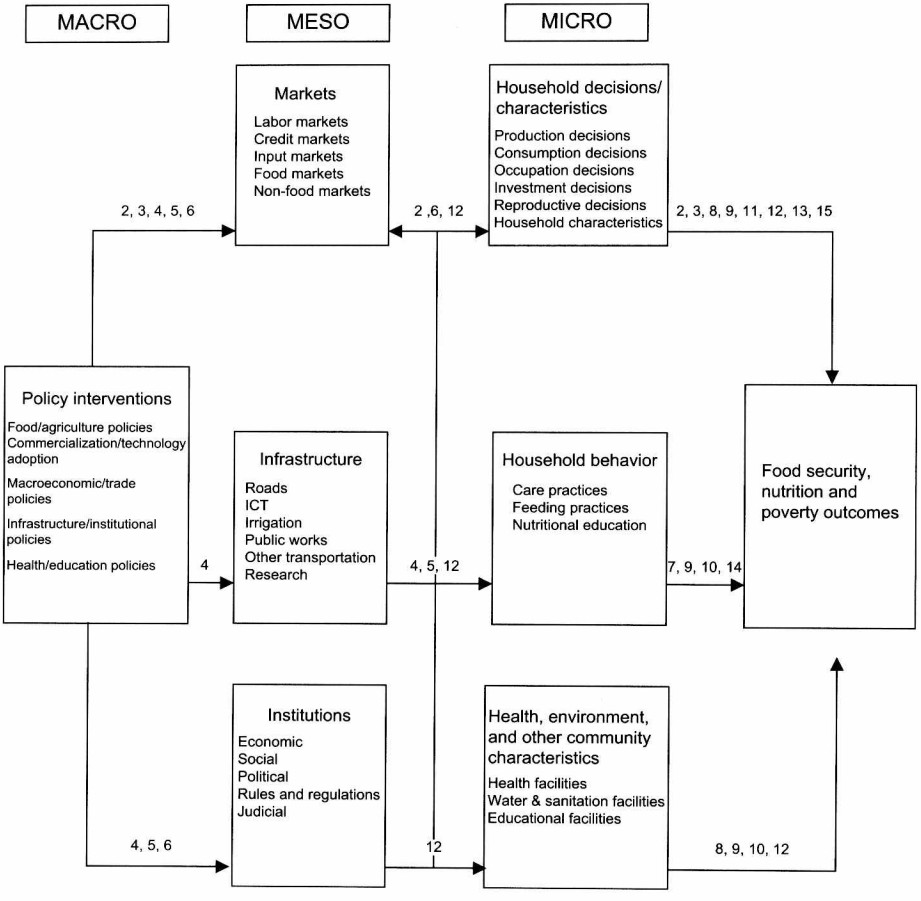

Figure I.1 Conceptual framework for designing food and nutrition security interventions*. *Numbers denote linkage across chapters in this book. (*Source*: adapted from Metz, 2000)

The main issues addressed in the chapters of this book relate to policy changes that affect food security through these markets. Infrastructure comprises the economic, social, as well as physical infrastructure; institutions are also affected by policy changes and affect household food security.

Changes induced by policies on different markets and on infrastructural factors affect household incomes, assets, human capital and household behavioral changes. The above factors in turn determine household food security as well as household resources devoted to food production. Income is one of the major determinants of household food security.

Both the supply and the demand factors determine the level of household food entitlement. *Household food security* is achieved if subsistence production and household food purchases are sufficient to meet the household food

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requirements. *Nutrition security*, on the other hand, is determined by a complex set of interactions between food and non-food determinants. For example, non-food determinants, such as the quality of health care facilities and services, education, sanitation, clean water, caring practices and effective mechanisms for delivering these services are important in improving the nutritional situation (IFPRI, 1995).

The above conceptual framework could be used to illustrate the linkages of the chapters of this book. Chapter 1 presents an introduction to the concepts, indicators and causal factors of household food security and nutritional outcomes.

In Chapter 2, we address the following issues:

1. to what extent adoption of new technologies improves household or individual food consumption
2. how does technology adoption in agriculture including post-harvest technologies translate into improved food security?

From the arrows in the diagram, we see that agricultural policies, such as technology adoption or commercialization, have close linkages to food and nutrition security, through securing food production and supply. The linkages are given by arrows bearing number 2.

Similarly, for example, Chapter 6 addresses the issue of how market access plays an important role in the agricultural food markets and thus affects household food security. Since marketing and pricing policies are affected by both supply and demand side of the food economy, it is important for national governments simultaneously to provide incentive prices to producers in order to increase their incomes and to protect consumers against rapid price fluctuations to ensure steady food supplies. One of the ways that government marketing and pricing policies can reduce price instability is by allowing the private sector to participate in the market along with state parastatals through alteration of the infrastructural and institutional policies that affect food markets. The linkages are given by arrows bearing number 6.

As another example, in Chapter 10, we address the pathways through which maternal education improves child health. These pathways help us in understanding the impact of community characteristics (such as presence of hospitals and water and sanitation conditions) on child nutritional status. Social infrastructure, such as the presence of medical centers and improved water and sanitation conditions, can be beneficial for certain subgroups of the population, such as the low-income and less educated households. The time saved by not traveling to a medical center can be reallocated to leisure, health production and other agricultural activities, which can improve household productivity and child nutritional status. As indicated by arrows with number 10, health and education policies, through their effect on markets and social infrastructure, can lead not only to improved provision of services but also alter household behavior through better child-care and hygienic practices, which can eventually improve child nutritional status.

Rationale for statistical methods illustrated in the book

Before launching into an analytical technique, it is important to have a clear understanding of the form and quality of the data. The form of the data refers to whether the data are categorical or continuous. The quality of the data refers to the distribution, i.e. to what extent it is normally distributed or not. Additionally, it is important to understand the magnitude of missing values in observations and to determine whether to ignore them or impute values to the missing observations. Another data quality measure is outliers and it is important to determine whether they should be removed.

Quantitative approaches in this book consist of descriptive, inferential and non-inferential statistics. Descriptive statistics organize and summarize information in a clear and effective way (for example, means and standard deviations). Inferential statistics analyze population differences, examine relationships between two or more variables and examine the effect of one variable or variables on other variables. The key distinction for inferential and non-inferential techniques is in whether hypotheses need to be specified beforehand. In the latter methods, normal distribution is not a pre-requisite. For example, in cluster analysis, one can use continuous or categorical variables to create cluster memberships and there is no need for a predefined outcome variable.

The choice and application of analytical tools is largely motivated by policy and program issues at hand and the type of data that is collected which, in turn, is related to the policy and program objectives. In inferential methods, users can draw inferences about the population from a sample because it provides a measure of precision or variation with regard to the sample data. Inferential methods generally focus on parameter estimation and its changes over time. The primary inferential procedures are confidence intervals and statistical tests. While confidence intervals can be used both for point and interval estimates, statistical tests are ways to determine the probability that a result occurs by chance alone.

Different objectives related to the question at hand and the types of data necessitate that the user choose an analysis from a number of possible approaches. The selection of a statistical procedure must consider the following key characteristics: independence of samples; type of data; equality of variances; and distribution assumptions. The conceptual diagram (Figure I.2) illustrates how an analysis can be undertaken using different approaches for bivariate and multivariate statistical procedures.

The conceptual diagram can be understood with the following questions and answers that lead to the appropriate statistical technique:

1. how many variables does the problem involve? For example, are there two variables or more than two variables?

   A question related to the first one is how does one want to treat the variables with respect to the scale of measurement? For example, are they both categorical (which

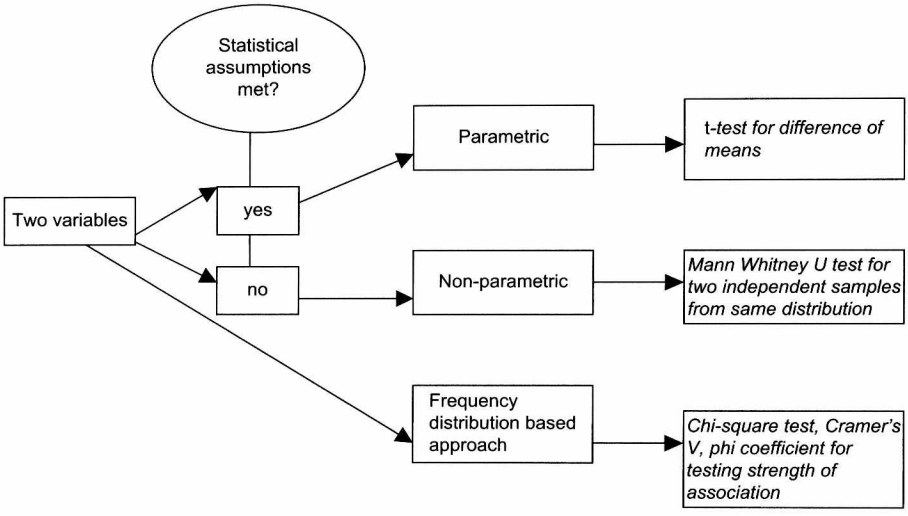

Figure I.2 Statistical procedures to test for determinants of food security, nutritional status and poverty.

includes nominal and ordinal variables)? Nominal variables are unordered categorical variables, such as sex of the child, while ordinal variables are ordered ones. For example, height of a child can be converted into short, average and tall.

2. what do we want to know about the distribution of the variables? For example, in the case of a continuous variable, is the distribution normal? One can test this condition by superimposing the normal density over the histogram of the variable or by drawing a Q-Q plot.

Examples of statistical tests used in this book

In the case of both the variables being nominal, with no distinction made between a dependent and an independent variable, one can measure association using a statistic based on the number of cases in each category. Various statistics based on the number of cases in each category are chi-square, Cramer's V and phi or the contingency coefficient as illustrated in Chapters 3 and 4.

In contrast, in the case of two variables being continuous and no distinction being made between a dependent and an independent variable, one can test whether the means on the two variables are equal (for example, in Chapter 2, we address whether food security differs between the hybrid maize growers versus non-growers). The difference of the means can be inferred using the *t*-test.

In the case of two variables, with one being nominal and the other continuous (the continuous variable being dependent), one can test the null hypothesis of statistical significance of differences between groups. By assuming homoscedasticity across levels of the independent variable, one can undertake an analysis of variance (ANOVA)/*F*-test. In Chapter 5, we address the issue of whether the

share of calories from various food groups differs across households classified by different expenditure brackets. Since the per capita expenditure of different food groups is continuous and the expenditure brackets are nominal, this approach is appropriate.

It is important to mention here by way of digression that while *t*- and *F*-tests are based on assumptions such as equal variances and normality, data are rarely examined prior to execution of the desired tests (we do not undertake non-parametric analysis in this book). There are instances when these assumptions may not be met. These include small samples and a non-normal distribution. In such cases, non-parametric tests may be appropriate. Also referred to as *distribution-free-methods*, non-parametric tests are not concerned with specific parameters, such as mean in an ANOVA analysis, but with the distribution of the variates (Sokal and Rohlf, 1981). Non-parametric analysis of variance is easy to compute and permits freedom from the distribution assumptions of an ANOVA. These tests are less powerful than parametric tests when the data are normally distributed. Under those circumstances, there is a greater likelihood of committing type II error using non-parametric tests. Some of the guidelines for deciding when to apply a non-parametric test are:

1. fewer than 12 cases
2. the sample is clearly not normally distributed
3. some values are excessively high or low.

However, it is important to bear in mind that non-parametric tests are counterparts to the parametric tests.

If the primary focus is to measure covariation (with no distinction made between dependent and independent variables), one can assign interval scaled values to the categories of the variable to compute the product moment correlation coefficient. The main question addressed here is: how much do the variables vary together (Sokal and Rohlf, 1981)? In Chapter 8, we illustrate this method with the different indicators of nutritional status such as height for age, weight for age and weight for height.

In contrast to correlation, in a regression analysis, a distinction is made between an independent and a dependent variable. If the dependent variable is continuous and one treats the relationship between the variables as linear, then coefficients from the linear regression can predict how much the dependent variable changes with respect to changes in the independent variables. In Chapter 9, we use this method to predict the values of child nutritional status from the values of individual/household and community characteristics.

We then proceed to multivariate analysis of data which allows the user to examine multiple variables using a single technique. While traditional univariate methods such as *t*-tests and chi-square tests can be very powerful, one can interpret the results based on the analysis of one manipulation variable. Multivariate techniques allow for the examination of many variables at once. There are different types of multivariate techniques that can be used to analyze food security, nutritional status and poverty analysis. Some of these techniques

such as multivariate regression, logistic regression, discriminant analysis, K-mean cluster analysis and factor analysis are used in this book. While these techniques can be very powerful, their results should be interpreted with care. Some techniques are sensitive to particular data types and require that data be distributed normally. Others cannot be used with non-linear variables (for example classification). Thus, while using these techniques, it is important to understand their respective intended uses, strengths, and limitations.

Continuing with our examples, with more than two variables we have the following: if there are more than two variables with a distinction being made between dependent (continuous) and independent variables (and relationship among the variables treated as additive and linear), the coefficients of multiple linear regression with their *t*-statistic will assign to each independent variable some of the explained variance in the dependent variable that the dependent variables shares with other independent variables. This method has been used in examining the role of maternal education and community characteristics on child nutritional status in Chapter 10.

In contrast to multivariate regression, when the dependent variable is categorical (either nominal or ordinal), the coefficients from the ordinal logit regression accompanied with the Wald statistic can tell us the probability associated with being in a particular category of the dependent variable. The idea can be illustrated with our example of determinants of poverty as in Chapter 12 as follows: suppose we want to examine the relationship between assets held by the household and probability of being poor. When the household has a very low level of assets, the probability of getting out of poverty is small and rises only slightly with increasing assets. But, at a certain point, the change of owning more assets begins to increase in an almost linear fashion, until eventually many households hold more assets, at which point the function levels off again. Thus, the outcome variable (in this case, the probability of being poor) varies from 0 to 1 since it is measured in probability.

Discriminant analysis, as introduced in Chapter 11, is used to determine which continuous variables discriminate between two or more naturally occurring groups. In this chapter, we investigate which variables discriminate between various levels of child nutritional status. This approach is particularly suitable, since it answers the questions: can a combination of variables be used to predict group membership (e.g. differentiating between low wasting from severe wasting) and which variables contribute to the discrimination between groups?

However, this method is more restrictive than logistic models, since the key assumption required is multivariate normality of the independent variables and equal covariance structure for the groups as defined by the dependent variable. If the sample sizes are small and the covariance matrices are unequal, then the estimation process can be adversely affected.

The method builds a linear discriminant function that can be used to classify the households. The overall fit is assessed by looking at the degree to which the group means differ (Wilks' lambda) and how well the model classifies. By looking at the correlation between the predictor variables and the discriminant

function, one can determine the discriminatory impact. This tool can help categorize a wasted child from a normal child.

We also explore data reduction and exploratory methods in the chapters of this book. In a cluster analysis, the main purpose is to reduce a large data set to meaningful subgroups of objects or households. The division is accomplished on the basis of similarity of the objects across a set of dimensions. The main problem with this method is outliers, which are often caused by including too many irrelevant variables. Secondly, it is also desirable to have uncorrelated factors. The analysis is especially important for exploring households that can be vulnerable in food insecurity and poverty dimensions. For example, this method can allow the researcher to identify households that are vulnerable in food insecurity dimension alone, households that are vulnerable in dimensions of poverty (such as lack of productive assets) and households that are vulnerable in both dimensions. The rules for developing clusters are, they should be different and measurable.

Finally, when there are many variables in a research design, it is often useful to reduce a large number of variables to a smaller number of factors. There is no distinction between dependent and independent variables and the relationships among variables are treated as linear. In this method, the researcher wants to explore the relationships among the set of variables by looking at the underlying structure of the data matrix. Multicollinearity is generally preferred between the variables, as the correlations are the key to data reduction. The '*KMO-Bartlett test*' is a measure of the degree to which every variable can be predicted by all other variables. This approach is suitable for constructing a food security index, since a large number of variables which are the main determinants of food security can be reduced to a smaller set of underlying components or factors that summarize the essential information in the variables. We use the principal component analysis to find the fewest number of variables that explain most of the variance. The new set of variables is created as linear combinations of the original set. In this procedure, if there were originally 15 variables that affected food security, the procedure can tell us which components explain a substantial percent of variability of the original set of 15 variables and thus reduce the number of factors to say 3. In essence, then, the number of variables to be analyzed has been reduced from 15 to 3.

Learning objectives

Each of the analytical chapters in this book addresses four sets of learning objectives. First, each chapter is theme based. A thematic policy issue is chosen and introduced to provide motivation and discussion for policy analysis. As part of this introduction, students are introduced to selected case studies of policy analysis and research that address the chosen theme from various geographical, eco-regional and policy contexts. Additional literature relevant to the theme is also reviewed.

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