

Table of contents

[View table of contents >>](#)

Preface

Acknowledgments

I INTRODUCTION AND BACKGROUND

1 Introduction

1.1 Causal Relationships and Ceteris Paribus Analysis

1.2 Stochastic Setting and Asymptotic Analysis

1.2.1 Data Structures

1.2.2 Asymptotic Analysis

1.3 Some Examples

1.4 Why Not Fixed Explanatory Variables?

2 Conditional Expectations and Related Concepts in Econometrics

2.1 Role of Conditional Expectations in Econometrics

2.2 Features of Conditional Expectations

2.2.1 Definition and Examples

2.2.2 Partial Effects, Elasticities, and Semielasticities

2.2.3 Error Form of Models of Conditional Expectations

2.2.4 Some Properties of Conditional Expectations

2.2.5 Average Partial Effects

2.3 Linear Projections

Problems

Appendix 2A

2.A.1 Properties of Conditional Expectations

2.A.2 Properties of Conditional Variances and Covariances

2.A.3 Properties of Linear Projections

3 Basic Asymptotic Theory

3.1 Convergence of Deterministic Sequences

3.2 Convergence in Probability and Boundedness in Probability

3.3 Convergence in Distribution

3.4 Limit Theorems for Random Samples

3.5 Limiting Behavior of Estimators and Test Statistics

3.5.1 Asymptotic Properties of Estimators

3.5.2 Asymptotic Properties of Test Statistics

Problems

II LINEAR MODELS

4 Single-Equation Linear Model and Ordinary Least Squares Estimation

- 4.1 Overview of the Single-Equation Linear Model
- 4.2 Asymptotic Properties of Ordinary Least Squares
 - 4.2.1 Consistency
 - 4.2.2 Asymptotic Inference Using Ordinary Least Squares
 - 4.2.3 Heteroskedasticity-Robust Inference
 - 4.2.4 Lagrange Multiplier (Score) Tests
- 4.3 Ordinary Least Squares Solutions to the Omitted Variables Problem
 - 4.3.1 Ordinary Least Squares Ignoring the Omitted Variables
 - 4.3.2 Proxy Variable–Ordinary Least Squares Solution
 - 4.3.3 Models with Interactions in Unobservables: Random Coefficient Models
- 4.4 Properties of Ordinary Least Squares under Measurement Error
 - 4.4.1 Measurement Error in the Dependent Variable
 - 4.4.2 Measurement Error in an Explanatory Variable Problems

5 Instrumental Variables Estimation of Single-Equation Linear Models

- 5.1 Instrumental Variables and Two-Stage Least Squares
 - 5.1.1 Motivation for Instrumental Variables Estimation
 - 5.1.2 Multiple Instruments: Two-Stage Least Squares
- 5.2 General Treatment of Two-Stage Least Squares
 - 5.2.1 Consistency
 - 5.2.2 Asymptotic Normality of Two-Stage Least Squares
 - 5.2.3 Asymptotic Efficiency of Two-Stage Least Squares
 - 5.2.4 Hypothesis Testing with Two-Stage Least Squares
 - 5.2.5 Heteroskedasticity-Robust Inference for Two-Stage Least Squares
 - 5.2.6 Potential Pitfalls with Two-Stage Least Squares
- 5.3 IV Solutions to the Omitted Variables and Measurement Error Problems
 - 5.3.1 Leaving the Omitted Factors in the Error Term
 - 5.3.2 Solutions Using Indicators of the Unobservables Problems

6 Additional Single-Equation Topics

- 6.1 Estimation with Generated Regressors and Instruments
 - 6.1.1 Ordinary Least Squares with Generated Regressors
 - 6.1.2 Two-Stage Least Squares with Generated Instruments
 - 6.1.3 Generated Instruments and Regressors
- 6.2 Control Function Approach to Endogeneity
- 6.3 Some Specification Tests
 - 6.3.1 Testing for Endogeneity
 - 6.3.2 Testing Overidentifying Restrictions
 - 6.3.3 Testing Functional Form
 - 6.3.4 Testing for Heteroskedasticity

6.4 Correlated Random Coefficient Models

6.4.1 When Is the Usual IV Estimator Consistent?

6.4.2 Control Function Approach

6.5 Pooled Cross Sections and Difference-in-Differences Estimation

6.5.1 Pooled Cross Sections over Time

6.5.2 Policy Analysis and Difference-in-Differences Estimation Problems

Appendix 6A

7 Estimating Systems of Equations by Ordinary Least Squares and Generalized Least Squares

7.1 Introduction

7.2 Some Examples

7.3 System Ordinary Least Squares Estimation of a Multivariate Linear System

7.3.1 Preliminaries

7.3.2 Asymptotic Properties of System Ordinary Least Squares

7.3.3 Testing Multiple Hypotheses

7.4 Consistency and Asymptotic Normality of Generalized Least Squares

7.4.1 Consistency

7.4.2 Asymptotic Normality

7.5 Feasible Generalized Least Squares

7.5.1 Asymptotic Properties

7.5.2 Asymptotic Variance of Feasible Generalized Least Squares under a Standard Assumption

7.5.3 Properties of Feasible Generalized Least Squares with (Possibly Incorrect) Restrictions on the Unconditional Variance Matrix

7.6 Testing the Use of Feasible Generalized Least Squares

7.7 Seemingly Unrelated Regressions, Revisited

7.7.1 Comparison between Ordinary Least Squares and Feasible Generalized Least Squares for Seemingly Unrelated Regressions Systems

7.7.2 Systems with Cross Equation Restrictions

7.7.3 Singular Variance Matrices in Seemingly Unrelated Regressions Systems

7.8 The Linear Panel Data Model, Revisited

7.8.1 Assumptions for Pooled Ordinary Least Squares

7.8.2 Dynamic Completeness

7.8.3 Note on Time Series Persistence

7.8.4 Robust Asymptotic Variance Matrix

7.8.5 Testing for Serial Correlation and Heteroskedasticity after Pooled Ordinary Least Squares

7.8.6 Feasible Generalized Least Squares Estimation under Strict Exogeneity Problems

8 System Estimation by Instrumental Variables

- 8.1 Introduction and Examples
- 8.2 General Linear System of Equations
- 8.3 Generalized Method of Moments Estimation
 - 8.3.1 General Weighting Matrix
 - 8.3.2 System Two-Stage Least Squares Estimator
 - 8.3.3 Optimal Weighting Matrix
 - 8.3.4 The Generalized Method of Moments Three-Stage Least Squares Estimator
- 8.4 Generalized Instrumental Variables Estimator
 - 8.4.1 Derivation of the Generalized Instrumental Variables Estimator and Its Asymptotic Properties
 - 8.4.2 Comparison of Generalized Method of Moment, Generalized Instrumental Variables, and the Traditional Three-Stage Least Squares Estimator
- 8.5 Testing Using Generalized Method of Moments
 - 8.5.1 Testing Classical Hypotheses
 - 8.5.2 Testing Overidentification Restrictions
- 8.6 More Efficient Estimation and Optimal Instruments
- 8.7 Summary Comments on Choosing an Estimator

Problems

9 Simultaneous Equations Models

- 9.1 Scope of Simultaneous Equations Models
- 9.2 Identification in a Linear System
 - 9.2.1 Exclusion Restrictions and Reduced Forms
 - 9.2.2 General Linear Restrictions and Structural Equations
 - 9.2.3 Unidentified, Just Identified, and Overidentified Equations
- 9.3 Estimation after Identification
 - 9.3.1 Robustness-Efficiency Trade-off
 - 9.3.2 When Are 2SLS and 3SLS Equivalent?
 - 9.3.3 Estimating the Reduced Form Parameters
- 9.4 Additional Topics in Linear Simultaneous Equations Methods
 - 9.4.1 Using Cross Equation Restrictions to Achieve Identification
 - 9.4.2 Using Covariance Restrictions to Achieve Identification
 - 9.4.3 Subtleties Concerning Identification and Efficiency in Linear Systems
- 9.5 Simultaneous Equations Models Nonlinear in Endogenous Variables
 - 9.5.1 Identification
 - 9.5.2 Estimation
 - 9.5.3 Control Function Estimation for Triangular Systems
- 9.6 Different Instruments for Different Equations

Problems

10 Basic Linear Unobserved Effects Panel Data Models

- 10.1 Motivation: Omitted Variables Problem
- 10.2 Assumptions about the Unobserved Effects and Explanatory Variables
 - 10.2.1 Random or Fixed Effects?
 - 10.2.2 Strict Exogeneity Assumptions on the Explanatory Variables
 - 10.2.3 Some Examples of Unobserved Effects Panel Data Models
- 10.3 Estimating Unobserved Effects Models by Pooled Ordinary Least Squares
- 10.4 Random Effects Methods
 - 10.4.1 Estimation and Inference under the Basic Random Effects Assumptions
 - 10.4.2 Robust Variance Matrix Estimator
 - 10.4.3 General Feasible Generalized Least Squares Analysis
 - 10.4.4 Testing for the Presence of an Unobserved Effect
- 10.5 Fixed Effects Methods
 - 10.5.1 Consistency of the Fixed Effects Estimator
 - 10.5.2 Asymptotic Inference with Fixed Effects
 - 10.5.3 Dummy Variable Regression
 - 10.5.4 Serial Correlation and the Robust Variance Matrix Estimator
 - 10.5.5 Fixed Effects Generalized Least Squares
 - 10.5.6 Using Fixed Effects Estimation for Policy Analysis
- 10.6 First Differencing Methods
 - 10.6.1 Inference
 - 10.6.2 Robust Variance Matrix
 - 10.6.3 Testing for Serial Correlation
 - 10.6.4 Policy Analysis Using First Differencing
- 10.7 Comparison of Estimators
 - 10.7.1 Fixed Effects versus First Differencing
 - 10.7.2 The Relationship between the Random Effects and Fixed Effect Estimators
 - 10.7.3 The Hausman Test Comparing Random Effects and Fixed Effects Estimators Problems

11 More Topics in Linear Unobserved Effects Models

- 11.1 Generalized Method of Moments Approaches to the Standard Linear Unobserved Effects Model
 - 11.1.1 Equivalence between GMM 3SLS and Standard Estimators
 - 11.1.2 Chamberlain's Approach to Unobserved Effects Models
- 11.2 Random and Fixed Effects Instrumental Variables Methods
- 11.3 Hausman and Taylor-Type Models
- 11.4 First Differencing Instrumental Variables Methods
- 11.5 Unobserved Effects Models with Measurement Error
- 11.6 Estimation under Sequential Exogeneity
 - 11.6.1 General Framework
 - 11.6.2 Models with Lagged Dependent Variables
- 11.7 Models with Individual-Specific Slopes

- 11.7.1 Random Trend Model
 - 11.7.2 General Models with Individual-Specific Slopes
 - 11.7.3 Robustness of Standard Fixed Effects Methods
 - 11.7.4 Testing for Correlated Random Slopes
- Problems

III GENERAL APPROACHES TO NONLINEAR ESTIMATION

12 M-Estimation, Nonlinear Regression, and Quantile Regression

- 12.1 Introduction
 - 12.2 Identification, Uniform Convergence, and Consistency
 - 12.3 Asymptotic Normality
 - 12.4 Two-Step M-Estimators
 - 12.4.1 Consistency
 - 12.4.2 Asymptotic Normality
 - 12.5 Estimating the Asymptotic Variance
 - 12.5.1 Estimation without Nuisance Parameters
 - 12.5.2 Adjustments for Two-Step Estimation
 - 12.6 Hypothesis Testing
 - 12.6.1 Wald Tests
 - 12.6.2 Score (or Lagrange Multiplier) Tests
 - 12.6.3 Tests Based on the Change in the Objective Function
 - 12.6.4 Behavior of the Statistics under Alternatives
 - 12.7 Optimization Methods
 - 12.7.1 Newton-Raphson Method
 - 12.7.2 Berndt, Hall, Hall, and Hausman Algorithm
 - 12.7.3 Generalized Gauss-Newton Method
 - 12.7.4 Concentrating Parameters out of the Objective Function
 - 12.8 Simulation and Resampling Methods
 - 12.8.1 Monte Carlo Simulation
 - 12.8.2 Bootstrapping
 - 12.9 Multivariate Nonlinear Regression Methods
 - 12.9.1 Multivariate Nonlinear Least Squares
 - 12.9.2 Weighted Multivariate Nonlinear Least Squares
 - 12.10 Quantile Estimation
 - 12.10.1 Quantiles, the Estimation Problem, and Consistency
 - 12.10.2 Asymptotic Inference
 - 12.10.3 Quantile Regression for Panel Data
- Problems

13 Maximum Likelihood Methods

- 13.1 Introduction
- 13.2 Preliminaries and Examples

- 13.3 General Framework for Conditional Maximum Likelihood Estimation
 - 13.4 Consistency of Conditional Maximum Likelihood Estimation
 - 13.5 Asymptotic Normality and Asymptotic Variance Estimation
 - 13.5.1 Asymptotic Normality
 - 13.5.2 Estimating the Asymptotic Variance
 - 13.6 Hypothesis Testing
 - 13.7 Specification Testing
 - 13.8 Partial (or Pooled) Likelihood Methods for Panel Data
 - 13.8.1 Setup for Panel Data
 - 13.8.2 Asymptotic Inference
 - 13.8.3 Inference with Dynamically Complete Models
 - 13.9 Panel Data Models with Unobserved Effects
 - 13.9.1 Models with Strictly Exogenous Explanatory Variables
 - 13.9.2 Models with Lagged Dependent Variables
 - 13.10 Two-Step Estimators Involving Maximum Likelihood
 - 13.10.1 Second-Step Estimator Is Maximum Likelihood Estimator
 - 13.10.2 Surprising Efficiency Result When the First-Step Estimator Is Conditional Maximum Likelihood Estimator
 - 13.11 Quasi-Maximum Likelihood Estimation
 - 13.11.1 General Misspecification
 - 13.11.2 Model Selection Tests
 - 13.11.3 Quasi-Maximum Likelihood Estimation in the Linear Exponential Family
 - 13.11.4 Generalized Estimating Equations for Panel Data
- Problems
Appendix 13A

14 Generalized Method of Moments and Minimum Distance Estimation

- 14.1 Asymptotic Properties of Generalized Method of Moments
 - 14.2 Estimation under Orthogonality Conditions
 - 14.3 Systems of Nonlinear Equations
 - 14.4 Efficient Estimation
 - 14.4.1 General Efficiency Framework
 - 14.4.2 Efficiency of Maximum Likelihood Estimator
 - 14.4.3 Efficient Choice of Instruments under Conditional Moment Restrictions
 - 14.5 Classical Minimum Distance Estimation
 - 14.6 Panel Data Applications
 - 14.6.1 Nonlinear Dynamic Models
 - 14.6.2 Minimum Distance Approach to the Unobserved Effects Model
 - 14.6.3 Models with Time-Varying Coefficients on the Unobserved Effects
- Problems
Appendix 14A

IV NONLINEAR MODELS AND RELATED TOPICS

15 Binary Response Models

15.1 Introduction

15.2 The Linear Probability Model for Binary Response

15.3 Index Models for Binary Response: Probit and Logit

15.4 Maximum Likelihood Estimation of Binary Response Index Models

15.5 Testing in Binary Response Index Models

15.5.1 Testing Multiple Exclusion Restrictions

15.5.2 Testing Nonlinear Hypotheses about β

15.5.3 Tests against More General Alternatives

15.6 Reporting the Results for Probit and Logit

15.7 Specification Issues in Binary Response Models

15.7.1 Neglected Heterogeneity

15.7.2 Continuous Endogenous Explanatory Variables

15.7.3 Binary Endogenous Explanatory Variable

15.7.4 Heteroskedasticity and Nonnormality in the Latent Variable Model

15.7.5 Estimation under Weaker Assumptions

15.8 Binary Response Models for Panel Data

15.8.1 Pooled Probit and Logit

15.8.2 Unobserved Effects Probit Models under Strict Exogeneity

15.8.3 Unobserved Effects Logit Models under Strict Exogeneity

15.8.4 Dynamic Unobserved Effects Models

15.8.5 Probit Models with Heterogeneity and Endogenous Explanatory Variables

15.8.6 Semiparametric Approaches

Problems

16 Multinomial and Ordered Response Model

16.1 Introduction

16.2 Multinomial Response Models

16.2.1 Multinomial Logit

16.2.2 Probabilistic Choice Models

16.2.3 Endogenous Explanatory Variables

16.2.4 Panel Data Methods

16.3 Ordered Response Models

16.3.1 Ordered Logit and Ordered Probit

16.3.2 Specification Issues in Ordered Models

16.3.3 Endogenous Explanatory Variables

16.3.4 Panel Data Methods

Problems

17 Corner Solution Responses

17.1 Motivation and Examples

17.2 Useful Expressions for Type I Tobit

17.3 Estimation and Inference with the Type I Tobit Model

17.4 Reporting the Results

17.5 Specification Issues in Tobit Models

- 17.5.1 Neglected Heterogeneity
- 17.5.2 Endogenous Explanatory Models
- 17.5.3 Heteroskedasticity and Nonnormality in the Latent Variable Model
- 17.5.4 Estimating Parameters with Weaker Assumptions

17.6 Two-Part Models and Type II Tobit Model

- 17.6.1 Truncated Normal Hurdle Model
- 17.6.2 Lognormal Hurdle Model and Exponential Conditional Mean
- 17.6.3 Exponential Type II Tobit Model

17.7 Two-Limit Tobit Model

17.8 Panel Data Methods

- 17.8.1 Pooled Methods
- 17.8.2 Unobserved Effects Models under Strict Exogeneity
- 17.8.3 Dynamic Unobserved Effects Tobit Models

Problems

18. Count, Fractional, and Other Nonnegative Responses

18.1 Introduction

18.2 Poisson Regression

- 18.2.1 Assumptions Used for Poisson Regression and Quantities of Interest
- 18.2.2 Consistency of the Poisson QMLE
- 18.2.3 Asymptotic Normality of the Poisson QMLE
- 18.2.4 Hypothesis Testing
- 18.2.5 Specification Testing

18.3 Other Count Data Regression Models

18.3.1 Negative Binomial Regression Models

18.3.2 Binomial Regression Models

18.4 Gamma (Exponential) Regression Model

18.5 Endogeneity with an Exponential Regression Function

18.6 Fractional Responses

18.6.1 Exogenous Explanatory Variables

18.6.2 Endogenous Explanatory Variables

18.7 Panel Data Models

18.7.1 Pooled QMLE

18.7.2 Specifying Models of Conditional Expectations with Unobserved Effects

18.7.3 Random Effects Methods

18.7.4 Fixed Effects Poisson Estimation

18.7.5 Relaxing the Strict Exogeneity Assumption

18.7.6 Fractional Response Models for Panel Data

Problems

19. Censored Data, Sample Selection, and Attrition

19.1 Introduction

19.2 Data Censoring

- 19.2.1 Binary Censoring
 - 19.2.2 Interval Coding
 - 19.2.3 Censoring from Above and Below
 - 19.3 Overview of Sample Selection
 - 19.4 When Can Sample Selection Be Ignored?
 - 19.4.1 Linear Models: Estimation by OLS and 2SLS
 - 19.4.2 Nonlinear Models
 - 19.5 Selection on the Basis of the Response Variable: Truncated Regression
 - 19.6 Incidental Truncation: A Probit Selection Equation
 - 19.6.1 Exogenous Explanatory Variables
 - 19.6.2 Endogenous Explanatory Variables
 - 19.6.3 Binary Response Model with Sample Selection
 - 19.6.4 An Exponential Response Function
 - 19.7 Incidental Truncation: A Tobit Selection Equation
 - 19.7.1 Exogenous Explanatory Variables
 - 19.7.2 Endogenous Explanatory Variables
 - 19.7.3 Estimating Structural Tobit Equations with Sample Selection
 - 19.8 Inverse Probability Weighting for Missing Data
 - 19.9 Sample Selection and Attrition in Linear Panel Data Models
 - 19.9.1 Fixed and Random Effects Estimation with Unbalanced Panels
 - 19.9.2 Testing and Correcting for Sample Selection Bias
 - 19.9.3 Attrition
- Problems

20 Stratified Sampling and Cluster Sampling

- 20.1 Introduction
 - 20.2 Stratified Sampling
 - 20.2.1 Standard Stratified Sampling and Variable Probability Sampling
 - 20.2.2 Weighted Estimators to Account for Stratification
 - 20.2.3 Stratification Based on Exogenous Variables
 - 20.3 Cluster Sampling
 - 20.3.1 Inference with a Large Number of Clusters and Small Cluster Sizes
 - 20.3.2 Cluster Samples with Unit-Specific Panel Data
 - 20.3.3 Should We Apply Cluster-Robust Inference with Large Group Sizes?
 - 20.3.4 Inference When the Number of Clusters is Small
 - 20.4 Complex Survey Sampling
- Problems

21 Estimating Average Treatment Effects

- 21.1 Introduction
- 21.2 A Counterfactual Setting and the Self-Selection Problem
- 21.3 Methods Assuming Ignorability (or Unconfoundedness) of Treatment

- 21.3.1 Identification
- 21.3.2 Regression Adjustment
- 21.3.3 Propensity Score Analysis
- 21.3.4 Combining Regression Adjustment and Propensity Score Weighting
- 21.3.5 Matching Methods

- 21.4 Instrumental Variables Methods
 - 21.4.1 Estimating the Average Treatment Effect Using IV
 - 21.4.2 Correction and Control Function Approaches
 - 21.4.3 Estimating the Local Average Treatment Effect by IV

- 21.5 Regression Discontinuity Designs
 - 21.5.1 The Sharp Regression Discontinuity Design
 - 21.5.2 The Fuzzy Regression Discontinuity Design
 - 21.5.3 Unconfoundedness versus the Fuzzy Regression Discontinuity

- 21.6 Further Issues
 - 21.6.1 Special Considerations for Responses with Discreteness or Limited Range
 - 21.6.2 Multivalued Treatments
 - 21.6.3 Multiple Treatments
 - 21.6.4 Panel Data Problems

22 Duration Analysis

- 22.1 Introduction
- 22.2 Hazard Functions
 - 22.2.1 Hazard Functions without Covariates
 - 22.2.2 Hazard Functions Conditional on Time-Invariant Covariates
 - 22.2.3 Hazard Functions Conditional on Time-Varying Covariates
- 22.3 Analysis of Single-Spell Data with Time-Invariant Covariates
 - 22.3.1 Flow Sampling
 - 22.3.2 Maximum Likelihood Estimation with Censored Flow Data
 - 22.3.3 Stock Sampling
 - 22.3.4 Unobserved Heterogeneity
- 22.4 Analysis of Grouped Duration Data
 - 22.4.1 Time-Invariant Covariates
 - 22.4.2 Time-Varying Covariates
 - 22.4.3 Unobserved Heterogeneity
- 22.5 Further Issues
 - 22.5.1 Cox's Partial Likelihood Method for the Proportional Hazard Model
 - 22.5.2 Multiple-Spell Data
 - 22.5.3 Competing Risks Models
- Problems

References

Index