

Advances in Spatial Science

Editorial Board

Manfred M. Fischer
Geoffrey J.D. Hewings
Anna Nagurney
Peter Nijkamp
Folke Snickars (Coordinating Editor)

For further volumes:
<http://www.springer.com/series/3302>

Dong-Joo Moon

Congestion-Prone Services Under Quality Competition

A Microeconomic Analysis

 Springer

Ph.D. Dong-Joo Moon
Seoul National University
Institute for Environmental Planning
San 56-1 Shinlim-dong Gwanak-gu, Seoul
Korea (South)
djmoon@snu.ac.kr

Advances in Spatial Science ISSN 1430-9602
ISBN 978-3-642-20188-2 e-ISBN 978-3-642-20189-9
DOI 10.1007/978-3-642-20189-9
Springer Heidelberg Dordrecht London New York

Library of Congress Control Number: 2011944969

© Springer-Verlag Berlin Heidelberg 2012

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilm or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer. Violations are liable to prosecution under the German Copyright Law.

The use of general descriptive names, registered names, trademarks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

To My Family

Preface

This study presents new microeconomic analyses of congestion-prone services that comprise most services at the final consumption stage. This study is distinguished from other studies in that it accommodates two unique features of service markets: the importance of service quality in the decisions of both consumers and suppliers, and the difference between system throughput and physical service capacity. This study covers partial equilibrium analyses of both private and public congestion-prone services in two different circumstances: under no competition and competition among multiple options differentiated by service quality.

This monograph proposes a set of new modeling approaches for the following: consumer demands, service costs, profit-maximizing choices for firms, and policies for public services. Some of the modeling approaches proposed in this study apply and adapt existing microeconomic approaches, and others are newly proposed. The key unique feature common to all these modeling approaches is to employ service time as the variable that accommodates two important features of service markets: congestion delay and service quality competition.

The first application area of the proposed modeling approaches is to characterize the industrial structure of a service market under quality competition. Through analyses based on the modeling approaches, it is shown that interactions among consumers and suppliers endogenously determine the industrial organization type of each firm and allow the coexistence of multiple organization types in a market. Further, it is proved that a lower-quality service should charge a lower price and a lower service production cost so as to have a positive demand, and that a consumer with a larger wage tends to choose a higher-quality service.

The second application area of the new modeling approaches is to assess marketwise resource allocation efficiency for service markets under quality competition. One important topic advocates that the diversity of service quality is an independent and indispensable criterion, in addition to Pareto optimality, to judge marketwise resource allocation efficiency for service markets. The other important topic analyzes how innovative services contribute to improving resource allocation efficiency in market economies. Further, these analytical outcomes are applied to explaining agglomeration economies of large urban areas.

The third application area is to determine the applicability of analytical outcomes from the proposed modeling approaches to economic studies dealing with practical decision-making problems. From this perspective, we analyze a number of topics that have hitherto not been considered in existing studies. For example, we introduce a new method to develop statistical models for consumer choices from among options having different service qualities. We also illustrate a cost-benefit analysis that uses user time cost that can reflect service quality. In addition, we develop optimal pricing and investment rules for a public service under the constraint of insufficient government funds.

This monograph consists of one introductory chapter, Chap. 1; 12 chapters of analyses, grouped into four parts; and one concluding chapter, Chap. 14. Chapter 1 provides a brief overview of the overall analytical approach used in this study. Each part, composed of multiple chapters, introduces and analyzes one group of decision-making problems: utility maximization problems in Part I; cost minimization problems for public and private congestion-prone services in Part II; profit maximization problems for congestion-prone private services in Part III; and social welfare maximization problems for public services in Part IV. The final chapter, Chap. 14, summarizes and concludes this work.

The four different groups of decision-making problems, introduced above, form the backbone of all the mathematical and economic analyses in this monograph. The utility maximization and cost minimization problems are used to develop consumer demand and supplier cost functions, respectively. These two functions provide inputs to profit and social welfare maximization problems. Optimality conditions for profit maximization problems are utilized to depict the market equilibrium and industrial structure of service markets. Optimality conditions for social welfare maximization problems are utilized to characterize marketwise resource efficiency for a given service type and optimal policies for a given public service.

Each part is presented according to the following plan. Firstly, each part introduces a set of postulates and their behavioral implications for the approach to model one of the four types of decision-making problems introduced above. Subsequently, it presents a number of theorems developed from optimality conditions for the specific type of decision-making problem and suggests the economic implications of the theorems. Finally, the study applies and extends the preceding analyses to explore the range of topics necessary to understand the overall structure of service markets.

Mathematically, all decision-making models proposed here are formulated as nonlinear mathematical programming problems with constraints, including stochastic programming problems. Mathematical analyses to develop theorems and corollaries from the optimization problems rely mainly on elementary optimization theory and real analysis.

This monograph will be of interest to graduate students and researchers in economics and other fields that require knowledge of microeconomics, such as urban and transportation planning as well as business administration. The monograph as a whole can serve as a self-contained book useful to readers who want to

grasp the overall structure of service markets. The monograph can also be a useful reference for a number of important research themes in applied microeconomics and planning, such as consumer choice behaviors, the cost structure of public and private congestion-prone service systems, congestion pricing for public congestion-prone service systems, and agglomeration economies of large urban areas.

I am deeply grateful to Tchangho J. Kim at the University of Illinois at Urbana-Champaign for his encouragement and advice throughout this research. I also would like to take this opportunity to express gratitude to Dennis Epple at Carnegie Mellon University, who motivated me to tackle this economic study in spite of majoring in transportation planning at university. I also gratefully acknowledge the financial support of Seoul National University with funds from the BK21 Program of the Korean Government.

Finally, I greatly appreciate Barbara Fess in Springer for her kindness and cooperation in the process of publishing this monograph. I also express my deep gratitude to Julia Deems at Carnegie Mellon University and Scott Cowen from SF Creative Learning Solutions for their assistance in writing this manuscript.

Seoul, Korea

Dong-Joo Moon

Contents

1	Introduction: Preview of Analysis Approaches	1
1.1	Objectives of the Study	1
1.2	Modeling Approaches for Decision-Making Problems	3
1.3	Organization of the Study	7
1.4	Mathematical Notations for Decision-Making Problems	9

Part I Service Demand of Consumers

2	Service Demand of Consumer with Deterministic Perceptions	13
2.1	Introduction	13
2.2	Development of the Basic Choice Problem	15
2.2.1	Homogeneity of Consumer Production Functions	15
2.2.2	Quantification of Service Quality	18
2.2.3	Consumer Production Function	19
2.2.4	Modeling of the Basic Choice Problem	22
2.3	Optimal Choice of Consumers	24
2.3.1	Consistency of Implicit Prices	24
2.3.2	Revealed Preference Condition	27
2.3.3	An Illustration of Consumer Choices: Travel Choices	29
2.4	Other Topics for Demand Analyses	32
2.4.1	Service Demand Functions	32
2.4.2	Mathematical Properties of Qualitative Choice Problems	34
3	Extensions and Limitations of the Perception Approach	37
3.1	Introduction	37
3.2	Qualitative Choice Problems for One Prime Commodity	39
3.2.1	Choice of Service Times	39
3.2.2	Choice of Durable Goods and Service Options	41
3.2.3	Location Choice of Non-durable Service Options	42
3.2.4	Choice for Services Having Substitutes	44

- 3.3 Qualitative Choice Problems for Multiple Prime Commodities 46
 - 3.3.1 The Basic Choice Problem for Multiple Kinds of Services 46
 - 3.3.2 Housing Location Choice 49
- 3.4 Non-Qualitative Choice Problems 54
 - 3.4.1 Decreasing Returns in Prime Commodity Production 54
 - 3.4.2 Mode Choice of Work Trips 57
- 4 Service Demand of Consumers with Random Perceptions 61**
 - 4.1 Introduction 61
 - 4.2 The Stochastic Basic Choice Problem 63
 - 4.2.1 Consumer Production Function under Uncertainty 63
 - 4.2.2 Modeling of the Stochastic Basic Choice Problem 65
 - 4.2.3 Development of Point-Wise Kuhn-Tucker Conditions 67
 - 4.3 Expected Demand Functions 68
 - 4.3.1 Revealed Preference Condition under Uncertainty 68
 - 4.3.2 The Reduced Form for Random Net-Value-of-Times 70
 - 4.3.3 Development of Expected Demand Functions 73
 - 4.3.4 Economic Implications of Expected Demand Functions ... 76
 - 4.4 Extensions and Applications of the Stochastic Basic Choice Problem 78
 - 4.4.1 Extension to Choices for Durable Services 78
 - 4.4.2 Extension to Choices for Multiple Kinds of Services 80
 - 4.4.3 Comparison with Random Utility Theory 82
- 5 Comparative Statics and Elasticity of Expected Demand Functions 85**
 - 5.1 Introduction 85
 - 5.2 Quantitative Competition 87
 - 5.2.1 Conversion into Indefinite Integrals 87
 - 5.2.2 Comparative Statics of Expected Demand Functions 90
 - 5.2.3 Characterization of Perfectly Elastic Demands 93
 - 5.2.4 Necessary Conditions for Perfectly Elastic Demand 96
 - 5.3 Qualitative Competition 97
 - 5.3.1 Conversion into Iterated Indefinite Integrals 97
 - 5.3.2 Comparative Statics of Expected Demand Functions 100
 - 5.3.3 Characterization of Perfectly Elastic Demand 103
 - 5.4 Qualitative Competition under Identical Ordering Condition 105
 - 5.4.1 Identical Ordering Condition 105
 - 5.4.2 Demand Functions under Identical Ordering Condition 106
 - 5.4.3 Necessary Conditions for Perfectly Elastic Demand 110

- 5.5 Mixed Competition 114
 - 5.5.1 Conversion into Iterated Indefinite Integrals 114
 - 5.5.2 Comparative Statics of Expected Demand Functions 116
 - 5.5.3 Necessary Conditions for Perfectly Elastic Demand 118

Part II Cost Analyses for Congestion-Prone Service Systems

- 6 Cost Analyses for the Basic Service System 123**
 - 6.1 Introduction 123
 - 6.2 Development of the Basic Social Cost Minimization Problem .. 126
 - 6.2.1 Two Different Types of Service Time Functions 126
 - 6.2.2 Examples of Service Time Functions 128
 - 6.2.3 Modeling of the Social Cost Minimization Problem 130
 - 6.3 Cost Functions for the Basic Social Cost Minimization Problem 131
 - 6.3.1 Optimality Conditions 131
 - 6.3.2 The Social Marginal Cost of Throughput 134
 - 6.3.3 The Social Marginal Full Cost of Throughput 137
 - 6.3.4 Graphical Methods of Developing Various Social Costs .. 140
 - 6.4 Extensions to the Basic Quasi-Cost Minimization Problem 143
 - 6.4.1 Modeling of the Quasi-Cost Minimization Problem 143
 - 6.4.2 The Marginal Quasi-Cost of Throughput 145
 - 6.4.3 The Marginal Full Cost of Throughput 147
 - 6.4.4 Comparison Between Social and Private Value-of-Service-Times 148
- 7 Extensions of Cost Analyses for the Basic Service System 153**
 - 7.1 Introduction 153
 - 7.2 The Returns-to-Scale of the Basic Service System 154
 - 7.2.1 Relationship between Marginal Full and Marginal Capacity Costs 154
 - 7.2.2 Returns-to-Scale for Homogeneous Service Technology .. 157
 - 7.2.3 Returns-to-Scale for Non-homogeneous Service Technology 159
 - 7.3 Cost Functions of Other Service Systems 161
 - 7.3.1 The Service System with a Fixed Capacity 161
 - 7.3.2 The Service System with Variable Costs 163
 - 7.3.3 The Service System Serving Unsteady Demand Flows ... 168
 - 7.4 Examples of Cost Analyses 172
 - 7.4.1 Homogeneous Service Technology Serving Steady Demand Flows 172
 - 7.4.2 Non-homogeneous Service Technology Serving Steady Demand Flows 174
 - 7.4.3 Homogeneous Service Technology Serving Peaking Demands 176

Part III Decisions of Congestion-Prone Service Firms

8 The Equilibrium of Monopoly Service Markets 181

8.1 Introduction 181

8.2 Development of Profit Maximization Problems 183

8.2.1 Types of Congestion-Prone Services 183

8.2.2 Decision-Making Components of Service Firms 185

8.2.3 Representation of Service Time 186

8.2.4 User Equilibrium Condition 188

8.2.5 Modeling of the Basic Form of Profit Maximization Problems 190

8.3 Optimality Conditions for the Basic Form of Profit Maximization Problems 192

8.3.1 Development of Optimality Conditions 192

8.3.2 Implications of the Marginal Revenue Loss of Service Time 195

8.3.3 Characterization of Market Equilibrium 197

8.4 Extensions to Other Service Systems 200

8.4.1 Optimal Price under Short-Run Adjustments 200

8.4.2 The Service System with Variable Costs 203

8.4.3 The Service System with Peaking Demands 205

9 The Equilibrium of Competitive Service Markets 209

9.1 Introduction 209

9.2 Approaches to Market Equilibrium Analysis 211

9.2.1 The Basic Form of Profit Maximization Problems Under Competition 211

9.2.2 Implications of the Profit Maximization Problem 213

9.2.3 Types and Variables of Reaction Functions 214

9.2.4 Degeneracy of Service Demand Functions 216

9.3 Reaction by Consumers 218

9.3.1 User Equilibrium under the Non-degeneracy Condition .. 218

9.3.2 User Equilibrium under the Degeneracy Condition 219

9.3.3 Uniqueness of User Equilibrium 222

9.4 Reaction of Service Firms 223

9.4.1 Virtual Demand under the Non-degeneracy Condition ... 223

9.4.2 Virtual Demand under the Degeneracy Condition 225

9.4.3 Reaction of Firms under the Non-degeneracy Condition .. 229

9.4.4 Reaction of Firms under the Degeneracy Condition 230

9.5 Characterization of Market Equilibrium 234

9.5.1 Reaction Function of Consumers 234

9.5.2 Reaction Function of Service Firms 235

9.5.3 Existence of Market Equilibrium 237

10 The Industrial Structure of Service Markets 239

10.1 Introduction 239

10.2 The Taxonomy of Industrial Organization Types 241

 10.2.1 Geometric Representation of Equilibrium Demands 241

 10.2.2 Approximation of Demand Elasticity for Firms 245

 10.2.3 Characterization of Perfectly Elastic Demands 247

 10.2.4 Classification of Industrial Organization Types 249

10.3 The Relationship between Prices and Their Determinants 251

 10.3.1 Determinants of Price Choices: Homogeneous Service Technology 251

 10.3.2 Effect of Returns-to-Scale on Price Choices 254

 10.3.3 Causality between Price Choices and their Determinants 256

 10.3.4 Extensions to the Case of Non-homogeneous Service Technology 259

10.4 Effect of Diversified Consumer Perceptions 261

 10.4.1 Trade-Off between Price and Service Quality 261

 10.4.2 Effect of Consumer Income on Service Quality Choices 264

 10.4.3 Requirement for Profitable Options 266

10.5 Interpretation of Real Service Markets 267

 10.5.1 Effect of Socioeconomic Variables on Industrial Structure 267

 10.5.2 Examples for Coexistence of Multiple Industrial Organization Types 271

Part IV Social Welfare Issues for Congestion-Prone Services

11 Policies for Public Services under No Competition 277

11.1 Introduction 277

11.2 The Basic Form of Social Welfare Maximization Problems 279

 11.2.1 Modeling of the Social Welfare Maximization Problem 279

 11.2.2 Sensitivities of Utility Maximization Problems 282

 11.2.3 Development of Social Optimality Conditions 283

 11.2.4 Differences from Net Social Benefit Maximization Problems 287

11.3 Implications of First Best Social Optimality 288

 11.3.1 Characterization of Market Equilibrium 288

 11.3.2 Social Optimality Conditions for Lump Sum Taxation 291

 11.3.3 Pareto Optimality Conditions for Public Services 294

 11.3.4 A Graphical Illustration of Pareto-Optimal Resource Allocations 297

- 11.4 Second Best Choices Under Budget Constraints 301
 - 11.4.1 Development of Second Best Social Optimality Conditions 301
 - 11.4.2 Effect of Non-optimal Subsidies on Social Welfare 303
 - 11.4.3 The Effect of Non-optimal Subsidies on Governmental Choices 306

- 12 Policies for Public Services under Competition 311**
 - 12.1 Introduction 311
 - 12.2 Multiple Public Services in Competition under Government Control 313
 - 12.2.1 Sensitivities of Utility Maximization Problems 313
 - 12.2.2 Development of Social Optimality Conditions 315
 - 12.2.3 Marketwise Pareto Optimality Conditions under Competition 318
 - 12.3 A Public Service in Competition with Services beyond Government Control 321
 - 12.3.1 A Public Service in Competition with Private Services 321
 - 12.3.2 A Public Service in Competition with Public Substitutes 323
 - 12.3.3 Relationship Between Ownership and the Scope of Knowledge for Consumer Reaction 327

- 13 The Resource Allocation Efficiency of Service Markets 331**
 - 13.1 Introduction 331
 - 13.2 The Resource Allocation Efficiency of Submarkets 333
 - 13.2.1 Identification of Two Evaluation Criteria 333
 - 13.2.2 Resource Allocations under Perfect and Differentiated Competition 335
 - 13.2.3 Resource Allocations under Monopoly or Oligopolistic Competition 337
 - 13.3 Characterization of Innovations in Service Markets 339
 - 13.3.1 Innovations from the Standpoint of Profitability 339
 - 13.3.2 Innovations under Quantitative Competition 342
 - 13.3.3 Innovations under Qualitative Competition 343
 - 13.4 Contribution of Innovations to Resource Allocation Efficiency 345
 - 13.4.1 A Benefit-Cost Analysis for Innovative Services 345
 - 13.4.2 Consumer Benefit from Service Quality Diversity 350
 - 13.5 Progress of Resource Allocation Efficiency in Market Economies 354
 - 13.5.1 Dynamic Process of Improvements in Resource Allocation Efficiency 354
 - 13.5.2 An Illustrative Example: Agglomeration Economies for Large Urban Areas 356

14 Summary and Concluding Remarks	359
15 Appendices	367
Appendix A: Appendix to Part I	367
Appendix B: Appendix to Part II	388
Appendix C: Appendix to Part III	398
Appendix D: Appendix to Part IV	404
References	417
Index	421

