INCORPORATION OF COSTS OF ADJUSTMENT IN DEA MODELS: SELECTION OF OPTIMAL PATHS

Filadelfo de Mateo Gómez

Chemical Engineer, Universidad Católica de Valparaíso, Chile

Master of Science in Chemical Engineering, University of Houston, TX, USA

A thesis submitted for the degree of Doctor of Philosophy
of
The University of New England
Armidale, NSW, Australia

August, 2003

Declaration

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree or qualification.

I certify that any help received in the preparing of this thesis, and all sources used, have been acknowledged in this thesis.

Filadelfo de Mateo Gómez

TABLE OF CONTENTS

Page

ABSTRACT x

ACKNOWLEDGEMENTS xi

CHAPTER 1: INTRODUCTION

1.1 Motivation 1

1.2 Objectives and Main Results of this Study 2

1.3 Thesis Outline 5

CHAPTER 2: PRODUCTION FUNCTION, PRODUCTIVITY AND EFFICIENCY MEASUREMENT

2.1 Introduction 9

2.2 The Production Function 10

2.3 The Transformation Function 16

2.4 Optimising Behaviour 19

2.5 Technical, Allocative and Economic Efficiency 24

2.6 Productivity 33

2.7 Dynamic Models 35

2.8 Primal and Dual Dynamic Models 39

2.9 Conclusions 44

CHAPTER 3: FUNDAMENTALS OF DATA ENVELOPMENT ANALYSIS

3.1 Introduction 46

3.2 Productivity and the Primal DEA Problem 48

3.3 Technical Efficiency and the DEA Dual Problem 54

3.4 Returns to Scale 69

3.5 Optimising Behaviour and DEA Dual Formulation 77

3.6 Limitations of DEA 84

3.7 Conclusions 86

CHAPTER 4: A BASIC DEA MODEL FOR THE SELECTION OF OPTIMAL PATHS OF ADJUSTMENT

4.1 Introduction 87

4.2 Concepts and Definitions 90

4.3 Basic Model for the Selection of Optimal Paths of Adjustment 94

4.4 Application of the Basic Dual DEA Model for the Selection of Optimal Paths of Adjustment 104

4.5 Some Conclusions from the Example of Section 4.4 108

4.6 Conclusions 110

CHAPTER 5: EXTENSIONS TO THE BASIC MODEL FOR THE SELECTION OF OPTIMAL PATHS OF ADJUSTMENT

5.1 Introduction 111

5.2 Optimal Paths of Adjustment: Asymmetric Costs of Adjustment .. 112

5.3 Optimal Paths of Adjustment: Time Horizon Longer than Adjustment Time 113

5.4 Example. Asymmetric Costs of Adjustment and Time Horizon Longer than Adjustment Time 115

5.5 Optimal Paths of Adjustment: Dynamic Outputs 123

5.6 Dynamic Outputs Example 125

5.7 Incorporation of Quasi-fixed Variables..... 130

5.8 Incorporation of Capital Investment Constraint 135

5.9 General DEA Model for Optimal Paths of Adjustment 137

5.10 Conclusions 139

CHAPTER 6: DETERMINATION OF OPTIMAL PATHS FOR STORES OF THE CHILEAN RETAILING FIRM, DIJON

6.1 Introduction 141

6.2 An Overview of Dijon..... 142

6.3 Relevant Data for this Application 145

6.4 The Optimal Path of Adjustment Program for Dijon's Stores 150

6.5 Optimal Paths of Adjustment for Five Stores 153

6.6 Economic Results 162

6.7 Period-to-Period Changes of Weights of Stores..... 167

6.8 Expected Outputs with Variable Prices and Costs of Adjustment for Store 202 174

6.9 Optimal Outputs with Variable Prices and Costs of Adjustment for Store 202 177

6.10 Conclusions 182

CHAPTER 7: CONCLUSIONS

7.1 Summary 183

7.2 Opportunities for Further Research 188

APPENDIXES

Appendix 1	DATA FOR DIJON'S 35 STORES	191
Appendix 2	PRICES AND COST OF ADJUSTMENT	193
Appendix 3	DATA CORRELATION MATRIX	202
Appendix 4	OPTIMAL PATH OF ADJUSTMENT PROGRAM	204
Appendix 5	TECHNICAL, ALLOCATIVE AND ECONOMIC EFFICIENCIES MEASURED at INITIAL CONDITIONS: TARGETS FOR MINIMUM COST OF INPUTS	216
Appendix 6	OPTIMAL PATHS OF ADJUSTMENT PROGRAM FOR 35 DIJON STORES	219
Appendix 7	CONDITIONS TO MAKE ADJUSTMENTS	228

BIBLIOGRAPHY 232

LIST OF FIGURES

Figure 2.1	Representation of Single-Output and Single-Input Production Technology	13
Figure 2.2	Representation of One-Output, Two-Input Production Technology	16
Figure 2.3	Technical Efficiency: Input- and Output-Orientated Measurements	26

Figure 2.4 Input-Orientated Systems: Technical and Allocative Efficiencies where Inputs are per Unit of Output 27

Figure 3.1 Input-Orientated Technical Efficiency Measurement Constant Returns to Scale 59

Figure 3.2 λ_k Depends of the System's Orientation..... 63

Figure 3.3 Input- and Output-Orientated Technical Efficiency Measurement 65

Figure 3.4 Boundaries of Technology Exhibits Constant, Increasing and Deceasing Returns to Scale 71

Figure 3.5 Effect of Input Prices in Input-Price Efficient Firms 82

Figure 4.1 Optimal Paths of Adjustment for Firms 1 and 5 100

Figure 4.2 Model (4.3.3) as a Sequence of Fundamental Dual DEA Models 104

Figure 5.1 Optimal Path of Adjustment of Firm 4. Non-discretionary Input 2 135

LIST OF TABLES

Table 3.1 Input and Output Data for Five Firms 51

Table 3.2 Solution to Problem (3.2.3) for the Five Firms: Output-Orientated System and Constant Returns-to-Scale Technology 52

Table 3.3	Solution to Problem (3.3.4) for the Five Firms: Input-Orientated Technical Efficiency and Constant Returns-to-Scale Technology	57
Table 3.4	Solution to Problem (3.3.9) for the Five Firms: Output-Orientated Technical Efficiency and Constant Returns-to-Scale Technology	63
Table 3.5	Solution to Problem (3.4.1) for the Five Firms: Input-Orientated Technical Efficiency and Variable Returns-to-Scale Technology	76
Table 4.1	Inputs, Outputs, Prices and Costs of Adjustment	99
Table 4.2	Optimal Paths of Adjustment for the Five Firms	107
Table 5.1	Inputs, Outputs, Prices and Costs of Adjustment for Five Firms	115
Table 5.2	Optimal Path of Adjustment, Asymmetric Cost of Adjustment and Horizon Greater than the Time of Adjustment	118
Table 5.3	Input Targets for Firm 1	122
Table 5.4	Expansion Factors for Estimating Outputs, Prices, and Costs of Adjustment at Period t	126
Table 5.5	Optimal Paths of Adjustment. Dynamic Outputs, Asymmetric Costs of Adjustment, Dynamic Prices and Costs of Adjustment of Five Firms	129

Table 5.6	Discretionary and Non-discretionary Inputs, Outputs, Prices and Costs of Adjustment	133
Table 5.7	Optimal Path of Adjustment Problem (5.7.2)	133
Table 5.8	Cost of Inputs, Initial and Target Input Quantity Vector	134
Table 6.1	Optimal Paths of Adjustment for Five Stores	155
Table 6.2	Economic Results of Optimal Paths of Adjustment	164
Table 6.3	Slacks for Constant and Variable Weights of Peers for Store 202	168
Table 6.4	Different Paths of Adjustment and Same Target ..... Input Quantity Vector	169
Table 6.5	Full Different Paths of Adjustment and Target ..... Input Quantity Vector	171
Table 6.6	Input Quantity Vector, Technical and Economic Efficiency for Store 265	173
Table 6.7	Variable Outputs, Prices and Costs of Adjustment for Store 202	175
Table 6.8	Optimal Path of Adjustment: Constant and Variable Outputs, Prices and Costs of Adjustment for Store 202 ...	176
Table 6.9	Optimal Path of Adjustment: Optimal Output, Variable Price and Cost of Adjustment	179
Table 6.10	Optimal Path of Adjustment:. Period-to-Period Weights of Peers and Slacks	181

ABSTRACT

This study focuses on the optimisation of the economic objective of firms and on the determination of the optimal paths of adjustments of their inputs. The path of adjustment is the period-to-period sequence of adjustments that change the quantities of the inputs from the initial to the optimal target values. The target quantities of the inputs are optimal in the sense that they optimise the economic objective of the firm. The adjustment of inputs is feasible only if the present value of the costs of adjustments of inputs is no less than the present value of the reduction of the costs of the inputs.

Data Envelopment Analysis (DEA) is used to define the boundary of the technology or the transformation function for the productive process.

The period-to-period sequence of adjustments suggests a dynamic form of DEA. This dynamic form is derived from allowing DEA for a period-to-period change of peers and of their respective weights. The change of peers may be the deletion of a peer, the incorporation of a new peer or both changes simultaneously. A peer may increase, retain or decrease its weight.

The final dynamic DEA model considers time-varying outputs and time-varying technology. The final dynamic model reduces to the standard DEA model when time is not included in implicit or explicit form. A limitation of the model is that the expected or forecasted data are used as observed data.

The model is used in an empirical application to 35 stores of Dijon, a Chilean retailing firm.

ACKNOWLEDGEMENTS

There were two reasons why I became a Doctor of Philosophy student at the University of New England in 1999. The first reason is that the University of New England offers external candidature. Being a senior staff member (Secretary General) at the Universidad Adolfo Ibáñez in Chile, I was not able to undertake full-time candidature for a PhD degree. The second reason is that I learned of the international reputation of the staff in the Centre of Efficiency and Productivity Analysis (CEPA) within the Department of Econometrics at the University of New England.

I would like to acknowledge with gratitude and thanks my supervisors, Dr. George Battese, Dr. Tim Coelli and Dr. Christopher O' Donnell. Tim and Chris continuously steered my research from engineering criteria to key concepts of microeconomics, firm theory and Data Envelopment Analysis. Their technical expertise was a great help and inspiration. My month-long trips to Armidale for consultations with my supervisors during the last four years, have been very profitable and inspirational to me and greatly assisted me in my research.

Unfortunately for the University of New England, CEPA transferred to the University of Queensland in early 2003 after Prasada Rao, Tim Coelli and Chris O' Donnell accepted senior positions at the University of Queensland in 2002. I have appreciated the help that Tim and Chris have given me, even after their resignations from the University of New England.

George Battese agreed to be a co-supervisor during my candidature, despite the fact that his area of expertise in efficiency and productivity analysis is particularly with stochastic frontier production functions. Since his retirement from UNE in August 2002, George has patiently helped me to put this thesis together in a coherent way. He has helped transform my colloquial Texan/Spanish expressions to more formal Australian English.

I would like to thank Professor Prasada Rao and other former staff of CEPA and of the School of Economics for their friendly and receptive attitudes to me during my trips to the University of New England during July in each of the last four years.

I also wish to thank my employer, Universidad Adolfo Ibáñez, for the financial support that made possible this work.

I give thanks to my wife, Carmen Gloria, and to our daughters, Maricarmen and Monserrat, for their permanent support, their warm full understanding, and their unlimited love.