

Cambridge University Press

978-0-521-29761-5 - Economic Theory and Exhaustible Resources

P. S. Dasgupta and G. M. Heal

Frontmatter

[More information](#)

**ECONOMIC THEORY AND
EXHAUSTIBLE RESOURCES**

Cambridge University Press
978-0-521-29761-5 - Economic Theory and Exhaustible Resources
P. S. Dasgupta and G. M. Heal
Frontmatter
[More information](#)

THE CAMBRIDGE ECONOMIC HANDBOOKS

General Editors

J. M. KEYNES (Lord Keynes)	1922–1936
D. H. ROBERTSON (Sir Dennis Robertson)	1936–1946
C. W. GUILLEBAUD	1946–1956
C. W. GUILLEBAUD } MILTON FRIEDMAN }	1956–1966
C. W. GUILLEBAUD	1966–1971
F. H. HAHN	

Cambridge University Press

978-0-521-29761-5 - Economic Theory and Exhaustible Resources

P. S. Dasgupta and G. M. Heal

Frontmatter

[More information](#)

ECONOMIC THEORY AND EXHAUSTIBLE RESOURCES

By

P. S. DASGUPTA

PROFESSOR OF ECONOMICS IN THE UNIVERSITY OF CAMBRIDGE

G. M. HEAL

PROFESSOR OF ECONOMICS, COLUMBIA UNIVERSITY



Cambridge University Press
978-0-521-29761-5 - Economic Theory and Exhaustible Resources
P. S. Dasgupta and G. M. Heal
Frontmatter
[More information](#)

Published by the Press Syndicate of the University of Cambridge
The Pitt Building, Trumpington Street, Cambridge CB2 1RP
40 West 20th Street, New York, NY 10011-4211 USA
10 Stamford Road, Oakleigh, Melbourne 3166, Australia

© 1979 by P. S. Dasgupta and G. M. Heal

First published 1979 by James Nisbet and Company Limited,
Digswell Place, Welwyn, Herts, and Cambridge University Press
Reprinted 1981, 1985, 1988, 1992, 1993, 1995

ISBN 0 521 22991 X hardback
ISBN 0 521 29761 3 paperback

Transferred to digital printing 2001

Cambridge University Press
978-0-521-29761-5 - Economic Theory and Exhaustible Resources
P. S. Dasgupta and G. M. Heal
Frontmatter
[More information](#)

For our children
Bridget, Zubeida and Shamik

Cambridge University Press

978-0-521-29761-5 - Economic Theory and Exhaustible Resources

P. S. Dasgupta and G. M. Heal

Frontmatter

[More information](#)

PREFACE

A book on the economics of exhaustible resources requires no justification. A long book does. We had originally planned to write a monograph on the subject, more in keeping with the design of the Handbook Series, of which this volume is a member. Had we pursued this approach we would have been forced to assume a knowledge of resource allocation theory, and the book would have applied this directly to the subject matter at hand.¹ But the subject has recently attracted the attention of mathematicians, physicists, engineers, biologists and systems analysts as well, and we wanted to write for them too.

There was in fact another reason. Even the best graduate texts on resource allocation theory are often dry, and it is not uncommon for economics students to fail to see what questions such economic theorizing is designed to answer and why they might be worth asking. It occurred to us that exhaustible natural resources provide one with particularly good examples for illustrating resource allocation theory. There is therefore a good deal of interchange between resource allocation theory and its application to exhaustible resources in the chapters that follow. We have often raised a question that appears naturally to arise when one thinks of such resources, developed the relevant analysis in a more general context, and then gone back to address ourselves to the question we had originally asked. This second reason explains why we have attempted to write a text on resource allocation theory at the same time. It is entirely possible that we have not succeeded, even partially, in carrying out this enterprise. But it was clearly worth a try. At any event, we hope that this book will prove useful to the graduate student were he to use it in conjunction with the more established texts on the subject.

We have not attempted to avoid rigour in the analyses that follow, but we have avoided generality wherever we felt that it would distract the reader from the point we wished to make. The purist will find disquieting our two-asset, constant population model with which we analyse growth possibilities in an economy with exhaustible resources. He will look askance at our reliance on

¹ For such an exposition, see Herfindahl and Kneese (1974).

Cambridge University Press

978-0-521-29761-5 - Economic Theory and Exhaustible Resources

P. S. Dasgupta and G. M. Heal

Frontmatter

[More information](#)

viii

PREFACE

symmetric externalities in Chapters 3, 5, and 12. But we have tried throughout to make clear why we are appealing to what we think are strong special cases and to what extent the results are robust. The Notes at the end of the chapters are addressed directly to this and provide detailed references for more general analyses.

Our reliance on special cases has also enabled us to keep the mathematical analysis well within the reach of first-year graduate students studying economic theory. Nothing more than elementary analysis is assumed. We have avoided appealing directly to the calculus of variations since, for the problem at hand, as in Chapter 10, the arguments can be conducted without an appeal to it.

We have found great difficulty in arriving at a satisfactory title for the book. Our final choice probably goes to the heart of the contents. On occasion we have reported on applied work on the subject. Here our coverage is really rather narrow. Thus, for example, we have not reported on the important recent work of Professor Dale Jorgenson and his associates on energy use in different sectors of the American economy. This is partly because our understanding of these matters is not as expert as we would wish it to be; partly also because it would have taken us far afield and altered the structure of the book.

This book has gone through several drafts. Part of the first draft was written while the authors were visiting Stanford University during 1974–1976. We are most grateful to the US National Science Foundation and the Department of Economics at Stanford for making our visits possible. The first draft was used by us as a basis for lectures to graduate students at the London School of Economics, Stanford University, the University of Sussex and Yale University. We have gained much from the comments of the participants, too numerous to mention individually. For typing and duplication facilities of the several drafts we are most grateful to the London School of Economics, Stanford University and the University of Sussex. Much of the typing was done with great efficiency by Jean Krechnyak at Stanford University, and Jean Middleton and Katie Davis at the London School of Economics.

The authors have worked together on the subject matter of this book for several years now and we are jointly responsible for the book as a whole. However, we have not worked equally on all chapters. Dasgupta is primarily responsible for Chapters 3, 5, 6, 8, 9, 13 and 14; and Heal for Chapters 1, 4, 12, 15 and 16. Chapters 2, 7, 10 and 11 were written jointly.

Cambridge University Press

978-0-521-29761-5 - Economic Theory and Exhaustible Resources

P. S. Dasgupta and G. M. Heal

Frontmatter

[More information](#)

PREFACE

ix

We owe intellectual debts to many. Our greatest debt is to Frank Hahn who instructed us to write the book and gave us detailed comments on each draft. Our debt to him, we are inclined to believe, exceeds that which is normally accorded by authors to editors of series to which they are contributing. Pradeep Mitra and Robert Solow made extensive comments on the first draft. The final version reflects the impact of their comments. Our debt to Joseph Stiglitz is no less. We have gained much from discussions with him over several years. We have had useful discussions with A. K. Das Gupta, Carol Dasgupta, Paul David, Robert Dorfman, Robert Eastwood, Lucien Foldes, Richard Gilbert, Claude Henry, David Hendry, Farouzeh Khalatbari, Tjalling Koopmans, Eric Maskin, James Meade, David Newbery, William Nordhaus, Nathan Rosenberg, Amartya Sen, Michael Spence, Alister Ulph and John Wise. We are grateful to them all.

Partha Dasgupta

London School of Economics
and Political Science.Geoffrey Heal
July 1978

University of Sussex.

Cambridge University Press

978-0-521-29761-5 - Economic Theory and Exhaustible Resources

P. S. Dasgupta and G. M. Heal

Frontmatter

[More information](#)

CONTENTS

Chapter	Page
1. A PREVIEW	1
2. RESOURCE ALLOCATION IN A TIMELESS WORLD	11
Introduction	11
1. Equilibrium Concepts	11
2. The Prisoner's Dilemma: An Example	18
3. Competitive Equilibrium of a Private Ownership Economy	22
4. Competitive Equilibrium and Pareto Efficiency	31
Bibliographical Notes	37
3. EXTERNALITIES	39
Introduction	39
1. Market Equilibrium and Pareto Efficiency	39
2. Markets for Externalities	44
3. Pigouvian Taxes for Correcting Externalities	52
4. Common Property Resource or the Problem of the 'Common'	55
5. Some Examples of Common Property Resources	73
6. Asymmetrical Externalities and the Multiplicity of Tax Equilibria	78
7. Conclusions	92
Bibliographical Notes	93
4. INTERTEMPORAL EQUILIBRIUM	95
1. A Basic Result	95
2. Consistent Preference: A Mild Digression	98
3. The Basic Result: An Interpretation	99
4. Time Dated Commodities and Forward Markets: A General Account	100
5. Durables	103
6. The Arbitrage Equation	105
7. Commentary on Intertemporal Equilibrium	107
5. RENEWABLE RESOURCES: SOME ECOLOGICAL AND ENVIRONMENTAL MODELS	113
1. Population Growth Curves	113
2. The Own Rate of Return	118
3. Exploitation in the Absence of Regulations	119
4. Present Value Profit Maximizing Catch Policy 1: Catch obtained Costlessly	126
5. Present Value Profit Maximizing Catch Policy 2: Catch Requires Resources	134

Cambridge University Press

978-0-521-29761-5 - Economic Theory and Exhaustible Resources

P. S. Dasgupta and G. M. Heal

Frontmatter

[More information](#)

xii

CONTENTS

Chapter	Page
6. Optimal Regulatory Policy	141
7. Blue Whales: An Application	144
8. Revocable and Irrevocable Processes	148
Bibliographical Notes	151
6. EXHAUSTIBLE RESOURCES: AN INTRODUCTION	153
1. Extraction from a Single Competitive Industry: The Pure Royalty Case	153
2. A Socially Managed Exhaustible Resource	163
3. Resource Exhaustion in Finite Time	166
4. Extraction from a Single Competitive Industry: The Presence of Extraction Costs	167
5. Resource Depletion and Research and Development	181
6. Conclusions	190
Bibliographical Notes	192
7. PRODUCTION WITH EXHAUSTIBLE RESOURCES	193
1. Production Possibilities and Intertemporal Programmes	193
2. Essential and Inessential Exhaustible Resources	196
3. Static Efficiency—Economic and Thermodynamic	208
4. Efficient and Inefficient Programmes	213
5. The Social Rate of Return on Investment	220
6. Conclusion	224
Bibliographical Notes	225
8. RESOURCE DEPLETION AND CAPITAL ACCUMULATION IN A COMPETITIVE ECONOMY	227
1. The Perfect Myopic Foresight Case	227
2. The Measurement of Net National Product	244
3. Imperfect Short-run Foresight	246
4. Conclusions	253
Bibliographical Notes	253
9 MEASURABILITY, COMPARABILITY AND THE AGGREGATION OF INTERGENERATIONAL WELFARES	255
1. Market Mechanism and Intergenerational Distribution of Welfare	255
2. The Setting	258
3. Classical Utilitarianism	260
4. The Existence of a Utilitarian Optimum	265
5. Choice behind the Veil of Ignorance	269
6. Intuitionist Conceptions	275
7. Conclusion	281
Bibliographical Notes	281
10. THE OPTIMAL DEPLETION OF EXHAUSTIBLE RESOURCES	283
1. A General Argument	283
2. The Maxi-min Programme	288

Cambridge University Press
 978-0-521-29761-5 - Economic Theory and Exhaustible Resources
 P. S. Dasgupta and G. M. Heal
 Frontmatter
[More information](#)

CONTENTS		xiii
Chapter		Page
3. The 'Utilitarian' Optimum		292
4. Commentary on the Implications of 'Utilitarian' and Maxi-min Criteria		308
5. Extension to an Open Economy		313
Bibliographical Notes		320
11. IMPERFECT COMPETITION AND EXHAUSTIBLE RESOURCES		323
Introduction		323
1. Monopoly: the Basic Issues		323
2. The Role of Elasticity of Demand		325
3. Extraction Costs and Monopoly		333
4. Monopsony		334
5. Imperfect Competition		336
6. Asymmetrically placed Oligopolists: The Phenomenon of Limit Pricing		340
7. Resource-owning Cartel and Resource-owning Fringe		345
8. Oligopolistic Resource Markets: An Application on OPEC and the Oil Market		351
9. Conclusions		357
Bibliographical Notes		358
12. TAXATION OF EXHAUSTIBLE RESOURCES		361
Introduction		361
1. A Sales Tax		363
2. A Profits Tax		365
3. Royalties		367
4. A Capital Gains Tax		368
5. The Depletion Allowance		368
6. True Depletion Allowance		370
7. The U.K. Petroleum Revenue Tax		371
8. A Dynamic Version of the Problem of the Common		372
Bibliographical Notes		375
13. UNCERTAINTY, INFORMATION AND THE ALLOCATION OF RISK		377
Introduction		377
1. Risk Sharing, Fair Insurance Contracts and the Law of Large Numbers		378
2. Information and Its Value		388
3. Types of Uncertainty		395
4. Irrevocable Decisions and Option Values		397
5. Optimal Environmental Programmes under Uncertainty		400
Bibliographical Notes		409
14. UNCERTAINTY AND THE ALLOCATION OF RESOURCES		411
1. The Arrow-Debreu Theory of Contingent Markets		411

Cambridge University Press
 978-0-521-29761-5 - Economic Theory and Exhaustible Resources
 P. S. Dasgupta and G. M. Heal
 Frontmatter
[More information](#)

xiv

CONTENTS

Chapter	Page
2. The Production of Information: Research and Development	418
3. Uncertainty in Reserves and the Social Value of Exploration	427
4. Private Incentives for Exploration	433
Bibliographical Notes	437
15. PRICE MOVEMENTS IN RESOURCE MARKETS	439
Introduction	439
1. Externalities in a Dynamic Context	439
2. Absence of Forward Markets	440
3. Uninsurable Risks	448
4. The Price of Oil	449
5. Simulation Studies	452
6. Conclusions on Oil	453
7. The Influence of Interest Rates	454
8. The Work of Barnett and Morse	464
9. Conclusions	469
Bibliographical Notes	469
16. CONCLUSIONS	471
Introduction	471
1. The Behaviour of Markets	471
2. Planning	474
3. Research and Development	475
4. Are There Exhaustible Resources?	478
5. Final Remarks	479
Bibliographical Notes	480
BIBLIOGRAPHY	481
INDEX	497