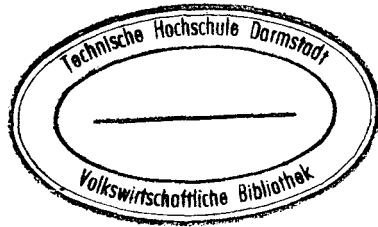


Toward a Formal Science of Economics

The Axiomatic Method in
Economics and
Econometrics

/ Bernt P. Stigum



The MIT Press
Cambridge, Massachusetts
London, England

Contents

- 1 Introduction 1
 - 1.1 The Need for a Formal Unitary Methodological Basis for the Science of Economics 1
 - 1.2 The Axiomatic Method and the Development of a Formal Science of Economics 3
 - 1.3 Formalism and the Unity of Science 13
 - 1.4 Noteworthy Results 18
 - 1.5 Acknowledgments 32

- 2 The Axiomatic Method 34
 - 2.1 Axioms and Undefined Terms 34
 - 2.2 Rules of Inference and Definition 35
 - 2.3 Universal Terms and Theorems 36
 - 2.4 Theorizing and the Axiomatic Method 36
 - 2.5 Pitfalls in the Axiomatic Method 37
 - 2.6 Theories and Models 38
 - 2.7 An Example 38

- I Mathematical Logic I: First-Order Languages 41**

- 3 Meaning and Truth 43
 - 3.1 A Technical Vocabulary 43
 - 3.2 Logical Syntax 46
 - 3.3 Semantics 47
 - 3.4 The Semantic Conception of Truth 48
 - 3.5 Truth and Meaning 51

- 4 The Propositional Calculus 54
 - 4.1 Symbols, Well-Formed Formulas, and Rules of Inference 54

- 4.2 Sample Theorems 55
- 4.3 The Intended Interpretation 58
- 4.4 Interesting Tautological Structures 60
- 4.5 Disjunction, Conjunction, and Material Equivalence 62
- 4.6 Syntactical Properties of the Propositional Calculus 64
- 4.7 Proof of the Tautology Theorem 65
- 5 The First-Order Predicate Calculus 68
 - 5.1 Symbols, Well-Formed Formulas, and Rules of Inference 68
 - 5.2 Sample Theorems 72
 - 5.3 Semantic Properties 78
 - 5.4 Philosophical Misgivings 83
 - 5.5 Concluding Remarks 86

II Mathematical Logic II: Theories and Models 89

- 6 Consistent Theories and Models 91
 - 6.1 First-Order Theories 92
 - 6.2 Proofs and Proofs from Hypotheses 93
 - 6.3 The Deduction Theorem 95
 - 6.4 Consistent Theories and Their Models 97
 - 6.5 The Compactness Theorem 98
 - 6.6 Appendix: Proofs 100
- 7 Complete Theories and Their Models 107
 - 7.1 Extension of Theories by Definitions 107
 - 7.2 Isomorphic Structures 112
 - 7.3 Elementarily Equivalent Structures 117
 - 7.4 Concluding Remarks 123
 - 7.5 Appendix 124
- 8 The Axiomatic Method and Natural Numbers 127
 - 8.1 Recursive Functions and Predicates 127
 - 8.2 Expression Numbers 131
 - 8.3 Representable Functions and Predicates 134
 - 8.4 Incompleteness of Consistent, Axiomatized Extensions of $T(N)$ 137
 - 8.5 The Consistency of $T(P)$ 140
 - 8.6 Concluding Remarks 144

- 9 Elementary Set Theory 146
 - 9.1 The Axioms of KPU 147
 - 9.2 The Null Set and Russell's Antinomy 151
 - 9.3 Unions, Intersections, and Differences 154
 - 9.4 Product Sets 156
 - 9.5 Relations and Functions 158
 - 9.6 Extensions 160
 - 9.7 Natural Numbers 161
 - 9.8 Admissible Structures and Models of KPU 168
 - 9.9 Concluding Remarks 169

III Economic Theory I: Consumer Choice 173

- 10 Consumer Choice under Certainty 175
 - 10.1 Universal Terms and Theorems 177
 - 10.2 A Theory of Choice, $T(H 1, \dots, H 6)$ 181
 - 10.3 The Fundamental Theorem of Consumer Choice 186
 - 10.4 The Hicks-Leontief Aggregation Theorem 191
- 11 Time Preference and Consumption Strategies 194
 - 11.1 An Alternative Interpretation of $T(H 1, \dots, H 6)$ 194
 - 11.2 The Time Structure of Consumer Preferences 196
 - 11.3 The Rate of Time Preference and Consumption Strategies 201
 - 11.4 Consumption Strategies and Price Indices 207
- 12 Risk Aversion and Choice of Safe and Risky Assets 212
 - 12.1 An Axiomatization of Arrow's Theory 213
 - 12.2 Absolute and Proportional Risk Aversion 216
 - 12.3 The Fundamental Theorems of Arrow 219
 - 12.4 New Axioms 223
 - 12.5 An Aggregation Problem 225
 - 12.6 Resolution of the Aggregation Problem 228
 - 12.7 Appendix: Proofs 236
- 13 Consumer Choice and Revealed Preference 259
 - 13.1 An Alternative Set of Axioms: $S 1, \dots, S 11$ 260
 - 13.2 The Fundamental Theorem of Revealed Preference 263
 - 13.3 The Equivalence of $T(S 1, \dots, S 11)$ and $T(H 1, \dots, H 5, \tilde{H} 6)$ 271

13.4	Concluding Remarks	277
14	Consumer Choice and Resource Allocation	279
14.1	Competitive Equilibria in Exchange Economies	279
14.2	Resource Allocation in Exchange Economies	282
14.3	The Formation of Prices in an Exchange Economy	286
14.4	Temporary Equilibria in an Exchange Economy	294
14.5	Admissible Allocations and Temporary Equilibria	304
14.6	On the Stability of Temporary Equilibria	306
IV	Probability Theory: Chance, Ignorance, and Choice	309
15	The Measurement of Probable Things	311
15.1	Experiments and Random Variables	312
15.2	Belief Functions	317
15.3	Probability Measures	326
15.4	Probability Distributions	334
15.5	Random Processes and Kolmogorov's Consistency Theorem	344
15.6	Two Useful Universal Theorems	348
16	Chance	351
16.1	Purely Random Processes	351
16.2	Games of Chance	354
16.3	The Law of Large Numbers	360
16.4	An Empirical Characterization of Chance	364
16.5	Chance and the Characteristics of Purely Random Processes	369
17	Ignorance	372
17.1	Epistemic versus Aleatory Probabilities	372
17.2	The Bayes Theorem and Epistemic Probabilities	378
17.3	Noninformative Priors	383
17.4	Measuring the Performance of Probability Assessors	388
18	Exchangeable Random Processes	391
18.1	Conditional Expectations and Probabilities	391
18.2	Exchangeable Random Variables	394
18.3	Exchangeable Processes and Econometric Practice	404
18.4	Conditional Probability Spaces	411

18.5 Exchangeable Processes on a Full Conditional Probability Space 415

18.6 Probability versus Conditional Probability 421

19 Choice under Uncertainty 422

19.1 The Decision Maker and His Experiment 422

19.2 The Decision Maker's Risk Preferences 424

19.3 Risk Preferences and Subjective Probability 428

19.4 Expected Utility 431

19.5 Assessing Probabilities and Measuring Utilities 439

19.6 Belief Functions and Choice under Uncertainty 445

V Nonstandard Analysis 457

20 Nonstandard Analysis 459

20.1 The Set of Urelements U 460

20.2 A Model of the Axioms for U 463

20.3 Elementarily Equivalent Structures and Transfer 467

20.4 Superstructures and Superstructure Embeddings 470

20.5 Transfer and Superstructure Embeddings 474

20.6 Internal Subsets of $W(*R)$ 477

20.7 Admissible Structures and the Nonstandard Universe 480

21 Exchange in Hyperspace 484

21.1 The Saturation Principle 484

21.2 Two Nonstandard Topologies 486

21.3 Exchange in Hyperspace by Transfer 494

21.4 Exchange in Hyperspace without Transfer 500

21.5 Concluding Remarks 506

22 Probability and Exchange in Hyperspace 508

22.1 Loeb Probability Spaces 508

22.2 Standard Versions of Loeb Probability Spaces 511

22.3 Random Variables and Integration in Hyperspace 514

22.4 Exchange in Hyperspace Revisited 520

22.5 A Hyperfinite Construction of the Brownian Motion 524

VI Epistemology 533

23 Truth, Knowledge, and Necessity 535

23.1 The Semantical Concept of Truth Revisited 535

- 23.2 Truth and Knowledge 537
- 23.3 The Possibility of Knowledge 538
- 23.4 Different Kinds of Knowledge 546
- 23.5 Necessity and Modal Logic 556

- 24 The Private Epistemological Universe, Belief, and Knowledge 566
 - 24.1 The Private Epistemological Universe 566
 - 24.2 Logical Probabilities and Their Possible-World Interpretation 576
 - 24.3 An Axiomatization of Knowledge 583
 - 24.4 Other Concepts of Knowledge 605

- 25 An Epistemological Language for Science 612
 - 25.1 Simple, Autonomous Relations 612
 - 25.2 Analogy and the Generation of Scientific Hypotheses 615
 - 25.3 Induction and Meaningful Sampling Schemes 619
 - 25.4 Many-Sorted Languages 622
 - 25.5 Semantic Properties of Many-Sorted Languages 628
 - 25.6 A Language for Science 629
 - 25.7 A Modal-Logical Apparatus for Testing Scientific Hypotheses 633
 - 25.8 Appendix: Proof of the Completeness Theorem for Many-Sorted Languages 640

VII Econometrics I: Empirical Analysis of Economic Theories 645

- 26 Empirical Analyses of Economic Theories 647
 - 26.1 Four Kinds of Theorems 647
 - 26.2 The Structure of an Empirical Analysis 651
 - 26.3 New Axioms and New Tests 666
 - 26.4 Superstructures, Data-Generating Mechanisms, the Encompassing Principle, and Meaningful Sampling Schemes 671

- 27 The Permanent-Income Hypothesis 679
 - 27.1 Formulation of the Hypothesis 679
 - 27.2 The Axioms of a Test of the Certainty Model: F_1, \dots, F_{17} 683

- 27.3 Theorems of $T(F_1, \dots, F_{17})$ 687
- 27.4 Confronting $T(F_1, \dots, F_{17})$ with Data 691
- 27.5 A Test of the Uncertainty Version of Friedman's Theory 700
- 27.6 Appendix: Standard Errors of Factor-Analytic Estimates 709

- 28 An Empirical Analysis of Consumer Choice among Risky and Nonrisky Assets 720
 - 28.1 The Axioms of the Empirical Analysis 720
 - 28.2 Arrow's Risk-Aversion Functions and the Data 726
 - 28.3 Comparative Risk Aversion 732
 - 28.4 Concluding Remarks 755

VIII Economic Theory II: Determinism, Uncertainty, and the Utility Hypothesis 759

- 29 Time-Series Tests of the Utility Hypothesis 761
 - 29.1 A Nonparametric Test of the Utility Hypothesis 762
 - 29.2 Testing for Homotheticity of the Utility Function 766
 - 29.3 Testing for Homothetic Separability of the Utility Function 768
 - 29.4 Excess Demand Functions and the Utility Hypothesis 771
 - 29.5 Nonparametric versus Parametric Tests of the Utility Hypothesis and a Counterexample 781

- 30 Temporary Equilibria under Uncertainty 785
 - 30.1 The Arrow-Debreu Consumer 785
 - 30.2 The Radner Consumer 789
 - 30.3 Consumer Choice under Uncertainty 795
 - 30.4 The Arrow-Debreu Producer 804
 - 30.5 Entrepreneurial Choice under Uncertainty 807
 - 30.6 Temporary Equilibria under Uncertainty 815
 - 30.7 Appendix: Proofs of Theorems 827

- 31 Balanced Growth under Uncertainty 840
 - 31.1 Balanced Growth under Certainty 844
 - 31.2 Balanced Growth under Uncertainty in an Indecomposable Economy 851
 - 31.3 Balanced Growth under Uncertainty in a Decomposable Economy 862

IX Econometrics II: Prediction, Distributed Lags, and Stochastic Difference Equations 869

- 32 Distributed Lags and Wide-Sense Stationary Processes 871
 - 32.1 A Characterization of Wide-Sense Stationary Processes 872
 - 32.2 Linear Least-Squares Prediction 884
 - 32.3 Distributed Lags and Optimal Stochastic Control 899

- 33 Trends, Cycles, and Seasonals in Economic Time Series and Stochastic Difference Equations 914
 - 33.1 Modeling Trends, Cycles, and Seasonals in Economic Time Series 914 /
 - 33.2 ARIMA Processes 921
 - 33.3 Dynamic Stochastic Processes 933
 - 33.4 Concluding Remarks on Multivariate Dynamic Stochastic Processes 940

- 34 Least Squares and Stochastic Difference Equations 946
 - 34.1 The Elimination of Trend, Cycle, and Seasonal Factors in Time Series 947
 - 34.2 Estimating the Coefficients in a Stochastic Difference Equation: Consistency 962
 - 34.3 Estimating the Coefficients in a Stochastic Difference Equation: Limiting Distributions 974
 - 34.4 Concluding Remarks 983

- Notes 987
- Bibliography 996
- Index 1015