

# CONTENTS OF VOLUME I

Introduction to the Series	v
Contents of the Handbook	vii
Preface to the Handbook	xi
<b>Part 1 – MATHEMATICAL AND STATISTICAL METHODS IN ECONOMETRICS</b>	
<i>Chapter 1</i>	
<b>Linear Algebra and Matrix Methods in Econometrics</b>	
<b>HENRI THEIL</b>	<b>3</b>
1. Introduction	5
2. Why are matrix methods useful in econometrics?	5
2.1. Linear systems and quadratic forms	5
2.2. Vectors and matrices in statistical theory	7
2.3. Least squares in the standard linear model	8
2.4. Vectors and matrices in consumption theory	10
3. Partitioned matrices	12
3.1. The algebra of partitioned matrices	12
3.2. Block-recursive systems	14
3.3. Income and price derivatives revisited	15
4. Kronecker products and the vectorization of matrices	16
4.1. The algebra of Kronecker products	16
4.2. Joint generalized least-squares estimation of several equations	17
4.3. Vectorization of matrices	19
5. Differential demand and supply systems	20
5.1. A differential consumer demand system	20
5.2. A comparison with simultaneous equation systems	22
5.3. An extension to the inputs of a firm: A singularity problem	23
5.4. A differential input demand system	23
5.5. Allocation systems	25
5.6. Extensions	25
6. Definite and semidefinite square matrices	27
6.1. Covariance matrices and Gauss–Markov further considered	27
6.2. Maxima and minima	29
6.3. Block-diagonal definite matrices	30

<b>7. Diagonalizations</b>	<b>30</b>
7.1. The standard diagonalization of a square matrix	30
7.2. Special cases	32
7.3. Aitken's theorem	33
7.4. The Cholesky decomposition	34
7.5. Vectors written as diagonal matrices	34
7.6. A simultaneous diagonalization of two square matrices	35
7.7. Latent roots of an asymmetric matrix	36
<b>8. Principal components and extensions</b>	<b>37</b>
8.1. Principal components	37
8.2. Derivations	38
8.3. Further discussion of principal components	40
8.4. The independence transformation in microeconomic theory	40
8.5. An example	43
8.6. A principal component interpretation	44
<b>9. The modeling of a disturbance covariance matrix</b>	<b>45</b>
9.1. Rational random behavior	46
9.2. The asymptotics of rational random behavior	47
9.3. Applications to demand and supply	49
<b>10. The Moore–Penrose inverse</b>	<b>51</b>
10.1. Proof of the existence and uniqueness	51
10.2. Special cases	52
10.3. A generalization of Aitken's theorem	53
10.4. Deleting an equation from an allocation model	56
<b>Appendix A: Linear independence and related topics</b>	<b>57</b>
<b>Appendix B: The independence transformation</b>	<b>58</b>
<b>Appendix C: Rational random behavior</b>	<b>61</b>
<b>References</b>	<b>64</b>

*Chapter 2***Statistical Theory and Econometrics**

ARNOLD ZELLNER

	<b>67</b>
<b>1. Introduction and overview</b>	<b>68</b>
<b>2. Elements of probability theory</b>	<b>69</b>
2.1. Probability models for observations	70
2.2. Definitions of probability	71
2.3. Axiom systems for probability theory	74
2.4. Random variables and probability models	82
2.5. Elements of asymptotic theory	110
<b>3. Estimation theory</b>	<b>117</b>
3.1. Point estimation	117
3.2. Criteria for point estimation	118

4. Interval estimation: Confidence bounds, intervals, and regions	152
4.1. Confidence bounds	152
4.2. Confidence intervals	154
4.3. Confidence regions	156
5. Prediction	158
5.1. Sampling theory prediction techniques	159
5.2. Bayesian prediction techniques	162
6. Statistical analysis of hypotheses	164
6.1. Types of hypotheses	164
6.2. Sampling theory testing procedures	165
6.3. Bayesian analysis of hypotheses	169
7. Summary and concluding remarks	172
References	174

**Part 2 – ECONOMETRIC MODELS**

*Chapter 3*

**Economic and Econometric Models**

MICHAEL D. INTRILIGATOR

	181
1. Introduction and overview	182
2. Models and economic models	182
3. Comparative statics	186
4. Econometric models	187
4.1. Structural form	190
4.2. Reduced form	193
4.3. Final form	195
5. Identification	197
6. Some specific models	199
6.1. Demand models	199
6.2. Production models	202
6.3. Macroeconometric models	204
6.4. Other econometric models	206
7. Uses of econometric models	207
7.1. Structural analysis	208
7.2. Forecasting	209
7.3. Policy evaluation	212
8. Conclusion	215
References	216

*Chapter 4*

**Identification**

CHENG HSIAO

	223
1. Introduction	224
2. Basic concepts	226

3. Contemporaneous simultaneous equation models	227
3.1. The model	227
3.2. Observationally equivalent structures	228
3.3. Identification in terms of trivial transformations	231
3.4. Identification in terms of "linear estimable functions"	234
3.5. Examples	240
4. Dynamic models with serially correlated residuals	242
4.1. The model	242
4.2. Observationally equivalent structures	245
4.3. Linear restrictions on the coefficients	247
4.4. Additional information about the disturbances	251
5. Non-linear <i>a priori</i> constraints and covariance restrictions	255
5.1. Some useful theorems	255
5.2. Contemporaneous error-shock models	257
5.3. Covariance restrictions	265
6. Bayesian theory of identification and concluding remarks	271
Appendix	276
References	280

### Chapter 5

## Model Choice and Specification Analysis

EDWARD E. LEAMER	285
1. Introduction	286
2. Model selection with prior distributions	288
2.1. Hypothesis testing searches	289
2.2. Interpretive searches	296
3. Model selection with loss functions	304
3.1. Model selection with quadratic loss	306
3.2. Simplification searches: Model selection with fixed costs	311
3.3. Ridge regression	313
3.4. Inadmissibility	313
4. Proxy searches: Model selection with measurement errors	314
5. Model selection without a true model	315
6. Data-instigated models	317
7. Miscellaneous topics	320
7.1. Stepwise regression	320
7.2. Cross-validation	320
7.3. Goodness-of-fit tests	324
8. Conclusion	325
References	325

**Part 3 – ESTIMATION AND COMPUTATION**

*Chapter 6*

**Non-linear Regression Models**

<b>TAKESHI AMEMIYA</b>	<b>333</b>
1. Introduction	334
2. Single equation–i.i.d. case	336
2.1. Model	336
2.2. Asymptotic properties	337
2.3. Computation	341
2.4. Tests of hypotheses	347
2.5. Confidence regions	352
3. Single equation–non-i.i.d. case	354
3.1. Autocorrelated errors	354
3.2. Heteroscedastic errors	358
4. Multivariate models	359
5. Simultaneous equations models	362
5.1. Non-linear two-stage least squares estimator	362
5.2. Other single equation estimators	370
5.3. Non-linear simultaneous equations	375
5.4. Non-linear three-stage least squares estimator	376
5.5. Non-linear full information maximum likelihood estimator	379
<b>References</b>	<b>385</b>

*Chapter 7*

**Specification and Estimation of Simultaneous Equation Models**

<b>JERRY A. HAUSMAN</b>	<b>391</b>
1. Introduction	392
2. Model specification	396
3. Identification	402
4. Estimation	408
4.1. Single equation estimation	408
4.2. System estimation	413
4.3. Reduced-form estimation	417
4.4. Maximum likelihood estimation	418
4.5. Estimation with covariance restrictions	426
4.6. Other considerations	428
5. Specification tests	430
6. Non-linear specifications	436
<b>References</b>	<b>445</b>

*Chapter 8***Exact Small Sample Theory in the Simultaneous Equations Model**

<b>P. C. B. PHILLIPS</b>	<b>449</b>
1. Introduction	451
2. Simple mechanics of distribution theory	454
2.1. Primitive exact relations and useful inversion formulae	454
2.2. Approach via sample moments of the data	455
2.3. Asymptotic expansions and approximations	457
2.4. The Wishart distribution and related issues	459
3. Exact theory in the simultaneous equations model	463
3.1. The model and notation	463
3.2. Generic statistical forms of common single equation estimators	464
3.3. The standardizing transformations	467
3.4. The analysis of leading cases	469
3.5. The exact distribution of the IV estimator in the general single equation case	472
3.6. The case of two endogenous variables	478
3.7. Structural variance estimators	482
3.8. Test statistics	484
3.9. Systems estimators and reduced-form coefficients	490
3.10. Improved estimation of structural coefficients	497
3.11. Supplementary results on moments	499
3.12. Misspecification	501
4. A new approach to small sample theory	504
4.1. Intuitive ideas	504
4.2. Rational approximation	505
4.3. Curve fitting or constructive functional approximation?	507
5. Concluding remarks	508
References	510

*Chapter 9***Bayesian Analysis of Simultaneous Equation Systems**

<b>JACQUES H. DREZE and JEAN-FRANÇOIS RICHARD</b>	<b>517</b>
1. Introduction and summary	519
1.1. The simultaneous equation model	519
1.2. Bayesian inference and identification	521
1.3. Bayesian treatment of exact restrictions	522
1.4. Bayesian analysis of the reduced form	523
1.5. Bayesian analysis of the structural form	524
1.6. Summary	525
1.7. Bibliographical note	526
2. A special case	526
2.1. Limited information maximum likelihood estimation	526
2.2. A Bayesian analogue	529

2.3. The normalization issue	531
2.4. An application	533
3. Identification	535
3.1. Classical concepts	535
3.2. Posterior densities and identification	536
3.3. Prior densities and identification	537
3.4. Choice of models and identification	538
4. Reduced-form analytics	539
4.1. Natural-conjugate prior densities	539
4.2. Further results	541
5. Limited information analysis	544
5.1. Introduction	544
5.2. Parameterization and invariance	544
5.3. Posterior conditional densities and moments	550
5.4. Posterior marginal densities	552
5.5. An application	555
5.6. Normalization and invariance	557
5.7. Two generalizations	559
6. Full information analysis	561
6.1. Introduction	561
6.2. A special case	561
6.3. Extended natural-conjugate prior densities	563
6.4. Seemingly unrelated regression models	567
6.5. Two-equation models	568
6.6. Applications	571
7. Numerics	579
7.1. Introduction	579
7.2. Evaluation of poly- $t$ densities	579
7.3. Numerical integration	581
Appendix A: Elements of multivariate analysis	585
Appendix B: Proofs	589
Reference table	595
References	596

Chapter 10

Biased Estimation

G. G. JUDGE and M. E. BOCK	599
1. Introduction	601
2. Conventional statistical models, estimators, tests, and measures of estimator performance	603
2.1. Conventional estimators and tests	603
2.2. Measures of estimator performance	606
2.3. Bayes estimation	607

3. Some possibly biased alternatives	608
3.1. Exact non-sample information	609
3.2. Stochastic non-sample information	610
3.3. Inequality non-sample information	612
3.4. Parameter distribution information (prior)	615
3.5. Some remarks	617
4. Pre-test–variable selection estimators	617
4.1. Conventional equality pre-test estimator	618
4.2. Stochastic hypothesis pre-test estimator	621
4.3. Inequality hypothesis pre-test estimator	622
4.4. Bayesian pre-test estimators	625
4.5. Variable selection estimators	627
5. Conventional estimator inadmissibility and the Stein-rule alternatives	627
5.1. Estimation under squared error loss	628
5.2. Stein-like rules under weighted squared error loss	635
6. Some biased estimator alternatives for the stochastic regressor case	639
7. Biased estimation with nearly collinear data	641
7.1. A measure of “near” collinearity	641
7.2. Ridge-type estimators	642
7.3. Minimax ridge-type estimators	643
7.4. Generalized ridge estimators	644
7.5. A summary comment	645
8. Some final comments	645
References	647

### Chapter 11

#### Estimation for Dirty Data and Flawed Models

WILLIAM S. KRASKER, EDWIN KUH and ROY E. WELSCH	651
1. Introduction	652
2. Sources of model failure	658
3. Regression diagnostics	660
4. Bounded-influence regression	664
5. Aspects of robust inference	673
6. Historical background	676
7. Bounded influence estimates for a hedonic price index	678
7.1. The model	681
7.2. Partial plots	681
8. Bounded-influence estimation with endogenous explanatory variables	691
9. Resistant time-series estimation	693
10. Directions for further research	695
References	696



## Chapter 12

## Computational Problems and Methods

RICHARD E. QUANDT	699
1. Introduction	701
2. Matrix methods	702
2.1. Methods for solving $A\hat{\beta} = c$	703
2.2. Singular value decomposition	706
2.3. Sparse matrix methods	707
3. Common functions requiring optimization	707
3.1. Likelihood functions	707
3.2. Generalized distance functions	709
3.3. Functions in optimal control	710
4. Algorithms for optimizing functions of many variables	710
4.1. Introduction	710
4.2. Methods employing no derivatives	712
4.3. Methods employing first and second derivatives	717
4.4. Methods employing first derivatives	721
5. Special purpose algorithms and simplifications	724
5.1. Jacobi and Gauss-Seidel methods	724
5.2. Parke's Algorithm A	727
5.3. The EM algorithm	728
5.4. Simplified Jacobian computation	729
6. Further aspects of algorithms	730
6.1. Computation of derivatives	731
6.2. Linear searches	735
6.3. Stopping criteria	737
6.4. Multiple optima	738
7. Particular problems in optimization	740
7.1. Smoothing of non-differentiable functions	740
7.2. Unbounded likelihood functions and other false optima	742
7.3. Constraints on the parameters	744
8. Numerical integration	747
8.1. Monte Carlo integration	749
8.2. Polynomial approximations	750
8.3. Evaluation of multivariate normal integrals	751
8.4. Special cases of the multivariate normal integral	753
9. The generation of random numbers	755
9.1. The generation of uniformly distributed variables	756
9.2. The generation of normally distributed variables	757
References	760
List of Theorems	765
Index	767