LIKELIHOOD-BASED INFERENCE IN COINTEGRATED VECTOR AUTOREGRESSIVE MODELS

SØREN JOHANSEN





Contents

PART I THE STATISTICAL ANALYSIS OF COINTEGRATION

1	Introduction		3
	1.1	The vector autoregressive model	4
	1.2	Building statistical models	5
	1.3	Illustrative examples	7
	1.4	An outline of the contents	8
	1.5	Some further problems	10
2	The Vector Autoregressive Model		11
	2.1	The vector autoregressive process	11
	2.2	The statistical analysis of the VAR	17
	2.3	Misspecification tests	20
	2.4	The illustrative examples	23
3	Basic Definitions and Concepts		34
	3.1	Cointegration and common trends	34
	3.2	Exercises	42
4	Cointegration and Representation of Integrated		
	Varia	ables	45
	4.1	From AR to MA representation for $I(1)$ variables	45
	4.2	From MA to AR representation for $I(1)$	40
	4.2	variables	55
	4.3	The MA representation of $I(2)$ variables	57
	4.4	Exercises	62
5	The $I(1)$ Models and their Interpretation		70
	5.1	The $I(1)$ models for cointegration	70
	5.2	The parametrization of the $I(1)$ model	71
	5.3	Hypotheses on the long-run coefficients β	72
	5.4	Hypotheses on the adjustment coefficients α	77
	5.5	The structural error correction model	78
	5.6	General hypotheses	79
	5.7	Models for deterministic terms	80

x Contents

	5.8	Intervention and seasonal dummies	84
	5.9	Exercises	8
6	The Statistical Analysis of $I(1)$ Models		89
	6.1	Likelihood analysis of $H(r)$	89
	6.2	Models for the deterministic terms	98
	6.3	Determination of cointegrating rank	98
	6.4	Exercises	100
7	Hypothesis Testing for the Long-Run Coefficients β		104
	7.1	Degrees of freedom	104
	7.2	Linear restrictions on β	106
	7.3	Illustrative examples	112
	7.4	Exercises	120
8	Partial Systems and Hypotheses on α		12
	8.1	Partial systems	12
	8.2	Test of restrictions on α	124
	8.3	The duality between \hat{eta} and \hat{lpha}_{\perp}	128
	8.4	Exercises	131
9	The $I(2)$ Model and a Test for $I(2)$		132
	9.1	A statistical model for $I(2)$	132
	9.2	A misspecification test for the presence of $I(2)$	13^{2}
	9.3	A test for $I(2)$ in the Australian data	137
		Part II	
	Тне	PROBABILITY ANALYSIS OF COINTEGRATION	
10	Proba	ability Properties of $I(1)$ Processes	14:
	10.1	Finite sample results	14:
	10.2	Asymptotic results	143
	10.3	Exercises	149
11	The Asymptotic Distribution of the Test for		
	Cointegrating Rank		15
	11.1	Testing $\Pi = 0$ in the basic model	15
	11.2	The limit distribution of the test for	
		cointegrating rank	156
	11.3	Asymptotic properties of the test for $I(2)$	163
	11.4	Exercises	164

X1

12	Deter	mination of Cointegrating Rank	167
	12.1	Model without constant term	168
	12.2	Model with a constant term	170
	12.3	Models with a linear term	175
	12.4	Exercises	176
13	Asymptotic Properties of the Estimators		
	13.1	The mixed Gaussian distribution	177
	13.2	A convenient normalization of β	179
	13.3	Consistency of the estimators	180
	13.4	Asymptotic distribution of $\hat{\beta}$ and $\hat{\alpha}$	181
	13.5	More asymptotic distributions	187
	13.6	Likelihood ratio test for hypotheses on the long-	
		run coefficients eta	192
	13.7	Exercises	196
14	The Power Function of the Test for Cointegrating		
	Rank	under Local Alternatives	201
	14.1	Local alternatives	201
	14.2	Properties of the process under local	
		alternatives	202
	14.3	The local power of the trace test	206
	14.4		209
15	Simulations and Tables		211
	15.1	Simulation of the limit distributions	211
	15.2	Simulations of the power function	212
	15.3	· · · · · · · · · · · · · · · · · · ·	214
		Part III	
	Appl	ENDICES	
A	Some Mathematical Results		
	A.1	Eigenvalues and eigenvectors	219
		The binomial formula for matrices	228
	A.3	The multivariate Gaussian distribution	233
	A.4	Principal components and canonical	
		correlations	237
В	Weak Convergence of Probability Measures on \mathbb{R}^p and		
_	C[0,1]		239
	B.1		239
	\mathbf{D}^{1}	Weak convergence on R^p	239

xii Contents

B.	2 Weak convergence on $C[0,1]$	241
B.	3 Construction of measures on $C[0,1]$	244
В.	4 Tightness and Prohorov's theorem	245
В.	5 Construction of Brownian motion	247
B.	6 Stochastic integrals with respect to Brownian motion	248
B.	7 Some useful results for linear processes	250
References		
Subject Index		
Author Index		