Market Models

A Guide to Financial Data Analysis

Carol Alexander

• UNIVERSITAT S LIECHTENSTEIN Bibliothek

JOHN WILEY & SONS, LTD

Chichester • New York • Weinheim • Brisbane • Singapore • Toronto

Contents

Preface	XV
Acknowledgements	xvii
Part I: Volatility and Correlation Analysis	
Chapter 1: Understanding Volatility and Correlation	3
1.1 The Statistical Nature of Volatility and Correlation	4
1.2 Volatility and Correlation in Financial Markets	9
1.3 Constant and Time-Varying Volatility Models ~"	12
14 Constant and Time-Varying Correlation Models	14
1.5 Remarks on Implementing Volatility and Correlation Models	17
1.6 Summary *	18
Chapter 2: Implied Volatility and Correlation	21
2.1 Understanding Implied Volatility*	22
2.1.1 Volatility in a Black-Scholes World	23
2.1.2 Call and Put Implied Volatilities	26
2.1.3 Differences between Implied and Statistical Volatilities	28
2.2 Features of Implied Volatility*	30
2.2.1 Smiles and Skews	30
2.2.2 Volatility Term Structures	31
2.2.3 Volatility Surfaces	32
2.3 The Relationship between Prices and Implied Volatility	34
2.3.1 Equity Prices and Volatility Regimes	34
2.3.2 Scenario Analysis of Prices and Implied Volatility	38

An asterisk '*' denotes that illustrative software is on the CD. The password for the CD is available from http://www.wiley.co.uk/marketmodels.

3.1.4 When and How Should Historic Estimates Be Used?

2.3.3 Implications for Delta Hedging

Chapter 3: Moving Average Models

3.1 Historic Volatility and Correlation*

3.1.1 Definition and Application"

3.1.2 Historic Volatility in Financial Markets

3.1.3 Historic Correlation in Energy Markets"

2.4 Implied Correlation

viii	Contents	
3.2	Exponentially Weighted Moving Averages*	57
3.3	Constant Volatility and the Square Root of Time Rule	61
Ch	apter 4: GARCH Models	63
4.1	Introduction to Generalized Autoregressive Conditional	
	Heteroscedasticity	65
	4.1.1 Volatility Clustering	65
	4.1.2 The Leverage Effect	68
10	4.1.5 The Conditional Mean and Conditional Variance Equations	09 70
4.2	A 21 ARCH	70
	4.2.2 Symmetric GARCH*	72
	4.2.3 Integrated GARCH and the Components Model	75
	4.2.4 Asymmetric GARCH*	79
	4.2.5 GARCH Models for High-Frequency Data	82
4.3	Specification and Estimation of GARCH Models	84
	4.3.1 Choice of Data, Stability of GARCH Parameters	
	and Long-Term Volatility	84
	4.3.2 Parameter Estimation Algorithms	94
	4.3.3 Estimation Problems	96
	4.3.4 Choosing the Best GARCH Model	96
4.4	Applications of GARCH Models	97
	4.4.1 GARCH Volatility Term Structures*	98
	4.4.2 Option Pricing and Hedging	103
15	4.4.5 Smile Fitting	100
4.3	4.5.1 Time Verying Correlation	107
	4.5.1 Time-Varying Conclation	100
	4.5.2 Time-Varying Covariance Matrices Based on	112
	Univariate GARCH Models	1 14
Ch	apter 5: Forecasting Volatility and Correlation	117
5.1	Evaluating the Accuracy of Point Forecasts	119
	5.1.1 Statistical Criteria	121
	5.1.2 Operational Criteria	124
5.2	Confidence Intervals for Volatility Forecasts	126
	5.2.1 Moving Average Models	120
	5.2.2 GARCH Models 5.2.3 Confidence Intervals for Combined Forecasts	128
53	Consequences of Uncertainty in Volatility and Correlation	120
5.5	531 Adjustment in Mark-to-Model Value of an Option*	135
	5.3.2 Uncertainty in Dynamically Hedged Portfolios	138
		100

Part II: Modelling the Market Risk of Portfolios

Chapter 6: Principal Component Analysis	143
6.1 Mathematical Background	145

Contents	ix
6.2 Application to Term Structures*	147
6.2.1 The Trend, Tilt and Convexity Components of a	1.47
Single Yield Curve	147
6.2.2 Modelling Multiple Yield Curves with PCA	149
6.2.3 Term Structures of Futures Prices	153
6.5 Modeling volatility Smiles and Skews	154
6.3.1 PCA of Deviations from ATM volatility	157
6.3.2 The Dynamics of Fixed Strike volatilities in	150
C22 Decementarization of the Valatility Surface and	159
6.3.3 Parameterization of the volatility Surface and	1.67
Quantification of <i>ad/as</i>	10/
0.3.4 Summary	170
6.4 1 Multicallinearity	171
6.4.2 Missing Date	172
0.4.2 Missing Data	175
Chapter 7: Covariance Matrices	179
7.1 Applications of Covariance Matrices in Risk Management	180
7.1.1 The Variance of a Linear Portfolio	180
7.1.2 Simulating Correlated Risk Factor Movements	
in Derivatives Portfolios	182
7.1.3 The Need for Positive Semi-definite Covariance Matrices*	183
7.1.4 Stress Testing Portfolios Using the Covariance Matrix*	184
7.2 Applications of Covariance Matrices in Investment Analysis	186
7.2.1 Minimum Variance Portfolios	187
7.2.2 The Relationship between Risk and Return	189
7.2.3 Capital Allocation and Risk-Adjusted Performance	
Measures	193
7.2.4 Modelling Attitudes to Risk	194
7.2.5 Efficient Portfolios in Practice	198
7.3 The RiskMetrics Data	201
7.4 Orthogonal Methods for Generating Covariance Matrices	204
7.4.1 Using PCA to Construct Covariance Matrices	205
7.4.2 Orthogonal EWMA	206
7.4.3 Orthogonal GARCH -	210
7.4.4 'Splicing' Methods for Obtaining Large Covariance Matrices	221
1.4.5 Summary	227
Chapter 8: Risk Measurement in Factor Models	229
8.1 Decomposing Risk in Factor Models	230
8.1.1 The Capital Asset Pricing Model	230
8.1.2 Multi-factor Fundamental Models	233
8.1.3 Statistical Factor Models	. 235
8.2 Classical Risk Measurement Techniques*	236
8.2.1 The Different Perspectives of Risk Managers and	
Asset Managers	236
8.2.2 Methods Relevant for Constant Parameter Assumptions	237

Contents	xi
10.3 Applications of Normal-Mixture Distributions*	301
10.3.1 Covariance VaR Measures	302
10.3.2 Term Structure Forecasts of Excess Kurtosis	303
10.3.3 Applications of Normal Mixtures to Option	
Pricing and Hedging	305
Part III: Statistical Models for Financial Markets	
· · · · · · · · · · · · · · · · · · ·	
Chapter 11: Time Series Models	315
11.1 Basic Properties of Time Series	316
11.1.1 Time Series Operators	316
11.1.2 Stationary Processes and Mean-Reversion	317
11.1.3 Integrated Processes and Random Walks	320
11.1.4 Detrending Financial Time Series Data	322
11.1.5 Unit Root Tests*	324
11.1.6 Testing for the Trend in Financial Markets	328
11.2 Univariate Time Series Models	329
11.2.1 AR Models	329
11.2.2 MA Models	331
11.2.3 ARMA Models	-• 332
11.3 Model Identification*	333
11.3.1 Correlograms	333
11.3.2 Autocorrelation Tests	335
11.3.3 Testing Down	337
'11.3.4 Forecasting with ARMA Models	338
11.4 Multivariate Time Series	340
11.4.1 Vector Autoregressions	340
11.4.2 Testing for Joint Covariance Stationarity	341
11.4.3 Granger Causality	344
Chapter 12: Cointegration	247
12.1. Introducing Cointegration	347
12.1 Introducing Connegration	340
12.1.2 Common Trands and Long Dun Equilibria	250
12.2 Testing for Cointegration*	353
12.2.1 The Engle Granger Methodology	254
12.2.2. The Eligie-Oraliger Methodology	554 257
12.2.2 The Johansen Methodology	337
12.3 Error Correction and Causality	361
12.4 Cointegration in Financial Markets	300
12.4.1 Foreign Exchange	366
12.4.2 Spot and Futures	367
12.4.5 Commodities	367
12.4.4 Spread Options	. 367
12.4.5 Term Structures - ,	368
12.4.6 Market Integration	368
12.5 Applications of Cointegration to Investment Analysis	369
12.5.1 Selection and Allocation	370

12.5.2 Constrained Allocations	371
12.5.3 Parameter Selection	372
12.5.4 Long-Short Strategies	375
12.5.5 Backtesting	375
12.6 Common Features	381
12.6.1 Common Autocorrelation	385
12.6.2 Common Volatility	386
Chapter 13: Forecasting High-Frequency Data	380
13.1 High-Frequency Data	390
13.1.1 Data and Information Sources	390
13.1.2 Data Filters	391
13.1.2 Data Thers	301
13.1.4 Parametric Models of High Frequency Data	303
13.2 Noural Natworks	395
12.2.1 Architecture	395
12.2.2 Data Processing	207
12.2.2 Data Processing	2097
13.2.5 Backpropagation	398 200
13.2.4 Performance Measurement	399
13.2.5 Integration ~	400
13.3 Price Prediction Models Based on Chaotic Dynamics	401
13.3.1 Testing for Chaos	401
13.3.2 Nearest Neighbour Algorithms	403
13.3.3 Multivariate Embedding Methods	405
	100
L Linux Deservices	409
A.I Linear Regression*	409
A. 1.1 The Simple Linear Model	410
A. 1.2 Multivariate Models	412
A. 1.3 Properties of OLS Estimators	414
A. 1.4 Estimating the Covariance Matrix of the OLS Estimators	419
A.2 Statistical Inference	421
A.2.1 Hypothesis Testing and Confidence Intervals	421
A.2.2 Mests	424
A.2.3 /"-test	426
A.2.4 The Analysis of Variance	427
A.2.5 Wald, Lagrange Multiplier and Likelihood Ratio Tests	428
A.3 Residual Analysis	429
A.3.1 Autocorrelation	430
A.3.2 Unconditional Heteroscedasticity	432
A.3.3 Generalized Least Squares	433
A.4 Data Problems	436
A.4.1 Multicollinearity -	436
A.4.2 Data Errors	437
A.4.3 Missing Data	439
A.4.4 Dummy Variables	440
•	

Contents	xiii
A.5 Prediction	443
A.5.1 Point Predictions and Confidence Intervals A.5.2 Backtesting	443 444
A.5.3 Statistical and Operational Evaluation Methods	445
A.6 Maximum Likelihood Methods	447
A.6.1 The Likelihood Function, MLE and LR Tests A.6.2 Properties of Maximum Likelihood Estimators A.6.3 MLEs for a Normal Density Function	447 449 449
A.6.4 MLEs for Non-normal Density Functions	451
References	453
Tables	467
Index	475