

Contents

1	Introduction	1
1.1	Intent of This Book	1
1.2	The Seven Bridges of Königsberg	3
1.3	Fundamental Properties of Real Networks	4
1.4	Several Approaches in Network Studies	6
1.5	Advancements in Network Research	7
1.6	Network Science in Stata	9
1.7	Network Science in R	10
1.8	Network Science in Python	11
	References	11
2	Network Science: Concepts and Definitions	15
2.1	Graphs: Notation and Simple Matrix Algebra	15
2.2	Handling Network Data	21
2.3	Import and Generate Network Data in Stata, R, and Python	23
2.3.1	Stata Code and Output	24
2.3.2	R Code and Output	25
2.3.3	Python Code and Output	27
2.4	Bipartite Network and Projection to One-Mode	29
2.4.1	Stata Code and Output	30
2.4.2	R Code and Output	30
2.4.3	Python Code and Output	31
2.5	Network Visualization	31
2.5.1	Stata Code and Output	31
2.5.2	R Code and Output	32
2.5.3	Python Code and Output	33
2.6	Text Networks	33
2.6.1	Stata Code and Output	34
2.6.2	R Code and Output	34
2.6.3	Python Code and Output	35

2.7	Case Study Using R: Text Network on ECB Speeches for the Climate Crisis	35
2.8	Conclusions	47
	References	47
3	Network Metrics	49
3.1	Introduction	49
3.2	Paths	49
3.3	Density of Graphs	51
3.3.1	Stata Code and Output	52
3.3.2	R Code and Output	53
3.3.3	Python Code and Output	54
3.4	Centrality Measures	54
3.4.1	Degree Centrality	55
3.4.2	Node Strength	57
3.4.3	Closeness Centrality	58
3.4.4	Betweenness Centrality	59
3.5	Spectral Centrality Measures	60
3.5.1	Neighborhood	60
3.5.2	Jaccard Coefficient	61
3.5.3	Eigenvector Centrality	62
3.5.4	Katz Centrality	64
3.5.5	PageRank Centrality	66
3.6	Community Detection	68
3.6.1	Clustering Coefficient	68
3.6.2	Rich-Club	70
3.7	Homophily and Similarity	71
3.7.1	E-I Homophily Index	71
3.7.2	Cosine Similarity	74
3.8	Structural Holes	75
3.9	Entropy	77
3.9.1	Stata Code and Output	78
3.9.2	R Code and Output	79
3.9.3	Python Code and Output	82
3.10	Case Study Using Stata: Innovation Networks through Patent Data	84
3.11	Conclusion	94
	References	95
4	Theoretical Models of Networks	97
4.1	Introduction	97
4.2	Erdős–Rényi Random Networks	98
4.2.1	Stata Code and Output	101
4.2.2	R Code and Output	102
4.2.3	Python Code and Output	103
4.2.4	Community Structures in Random Networks	103

4.2.5	R Code and Output	106
4.2.6	Python Code and Output	107
4.3	Core-Periphery Structure	108
4.4	The Small-World Concept	109
4.5	Barabási–Albert (BA) Model	112
4.5.1	Properties of the Barabási–Albert (BA) Model	113
4.5.2	Stata Code and Output	116
4.5.3	R Code and Output	117
4.5.4	Python Code and Output	119
4.6	Power-Law: A Formal Specification	121
4.6.1	Characteristics of Power-Law Distribution	122
4.6.2	Power-Law Distribution for Continuous and Discrete Data	123
4.6.3	R Code and Output	127
4.6.4	Python Code and Output	128
4.6.5	Power-Law Estimation from Empirical Data	129
4.6.6	R Code and Output	132
4.6.7	Python Code and Output	135
4.7	Case Study Using Python: Exploring Citation Distribution Through the Lens of Power-Law	136
4.8	Conclusions	144
	References	144
5	Statistical Social Network Models	147
5.1	Introduction	147
5.2	Logistic Model	148
5.2.1	Stata Code and Output	153
5.2.2	R Code and Output	153
5.2.3	Python Code and Output	154
5.3	Multiple Regression QAP	154
5.3.1	Stata Code and Output	156
5.3.2	R Code and Output	157
5.4	Bernoulli Graph Models and P Models	157
5.5	Exponential Random Graph Model (ERGM) for Binary Data	159
5.5.1	Python Code and Output	165
5.5.2	The Probability Distribution of ERGMs	166
5.5.3	ERGM as Markovian Model	168
5.5.4	Sufficient Statistics	169
5.6	Estimation of ERGMs	171
5.6.1	Markov Chain Monte Carlo (MCMC)	173
5.6.2	Metropolis–Hastings Algorithm	174
5.6.3	R Code and Output	177
5.6.4	Python Code and Output	178
5.6.5	Python Code and Output	180

5.7	Goodness-of-Fit for Dyadic Dependence Models	183
5.7.1	R Code and Output.	184
5.7.2	R Code and Output.	186
5.8	Marginal Effects in ERGM for Binary Data	187
5.8.1	R Code and Output.	188
5.9	ERGM for Count Data.	188
5.9.1	R Code and Output.	190
5.10	Degeneracy Issue	191
5.11	Temporal Exponential Random Graph Model (TERGM)	192
5.11.1	R Code and Output.	196
5.12	The Separable Temporal Exponential Random Graph Model (STERGM)	198
5.12.1	R Code and Output.	201
5.13	Generalized Exponential Random Graph Model (GERGM)	202
5.13.1	R Code and Output.	205
5.14	Stochastic Actor-Oriented Model.	208
5.14.1	Main Assumptions	209
5.14.2	Rate Function.	210
5.14.3	Objective Function.	211
5.14.4	Method of Moments.	212
5.14.5	R Code and Output.	218
5.15	Case Study Using R: Co-Patent Network Using a Temporal Exponential Random Graph Model.	220
5.15.1	Conclusions	229
5.16	Case Study Using R: A Friendship Network Using a Stochastic Actor-Oriented Model.	230
5.16.1	Data and Variables	231
5.16.2	Results	232
5.17	Conclusions	238
	References.	239