Contents

List of Figures xi
Preface xvi

1. ONTOLOGY 1

1.1 The naturalistic turn in economics and the physical nature of knowledge 1
  1.1.1 The changing nature of economics 1
  1.1.2 The meaning of ‘naturalism’ 2
  1.1.3 Natural Philosophy: Hegel and Peirce 4
  1.1.4 The Aristotelian notion of causal explanation 6
  1.1.5 The Principle of Bimodality 9
  1.1.6 Externalism and naturalism in economics 13

1.2 Towards a principled theory of economics: Impossibility theorems on mind 15
  1.2.1 Impossibility theorems and theory construction 15
  1.2.2 The Hayek impossibility theorem on brain and mind 18
  1.2.3 The gap between brain and mind 20
  1.2.4 Peircian triadism 21
  1.2.5 Minds are signs 24
  1.2.6 Naturalizing Wittgenstein’s ‘Private Language’ argument 26
  1.2.7 The externalist approach to brain and mind 27
  1.2.8 The two worlds 29
  1.2.9 Signs and existence 31

1.3 Observer relativity and the semiotic triad: Knowledge as a physical structure 32
  1.3.1 Observer independent and observer relative facts 32
  1.3.2 The emergence of information 34
  1.3.3 Fisher information and dynamic epistemics 36
  1.3.4 The fundamental semiotic triad in knowledge generation 38
  1.3.5 Semiotic realism and the semiiverse 44
  1.3.6 Physical information generation 46

1.4 Consilience and economic analysis 49
  1.4.1 Four approaches to reality 49
  1.4.2 Implications for economics as a science 52
  1.4.3 Consilience 56
2. CAUSATION

2.1 Thermodynamics and knowledge
   2.1.1 The conceptual framework of Thermodynamics
   2.1.2 Entropy and generation of information
   2.1.3 Entropy and observation

2.2 Randomness
   2.2.1 Entropy: The view from Natural Philosophy
   2.2.2 Randomness: Observer relative or observer independent?
   2.2.3 Lessons taught by Maxwell’s demon
   2.2.4 Propensities and probabilities
   2.2.5 ‘Individuals’ as a fundamental ontological category

2.3 Emergent information and the Second Law
   2.3.1 Regularities as kinds of constraints on change
   2.3.2 Evolution of knowledge as evolution of constraints
   2.3.3 Growth of knowledge as expression of the Second Law
   2.3.4 Irreversibility and causation
   2.3.5 The Second Law and finality
   2.3.6 Triadic causal modes, generation of information
     and irreversibility

2.4 Functions and Maximum Entropy Production
   2.4.1 Fundamental forms of functions
   2.4.2 Autocatalytic functions and hypercycles
   2.4.3 Lotka’s Maximum Power Principle
   2.4.4 Maximum Power and Maximum Entropy Production
   2.4.5 Maximum Entropy Production and the Constructal Law

2.5 Physisosemiosis and Gaia
   2.5.1 Kauffman’s ‘Fourth Law’ restated in triadic terms
   2.5.2 PIDs as self-referential heat engines
   2.5.3 A measure for evolving information in physisosemiosis
   2.5.4 Emergent hierarchies in physisosemiosis and ‘Gaia’
   2.5.5 Maximum Entropy Production in the Earth System

3. EVOLUTION

3.1 Evolution, entropy and information
   3.1.1 The meanings of ‘evolution’
   3.1.2 Dissipation of energy and origins of life
   3.1.3 Entropy and evolution: Fundamentals
   3.1.4 Evolution maximizes Fisher information

3.2 The theory of selection
   3.2.1 Price’s equation and heredity
   3.2.2 Fisher’s ‘Fundamental Theorem’ as an impossibility theorem
3.2.3 Fitness and maximum entropy 152

3.3 Hiearchies and the many dimensions of evolution 157
  3.3.1 Synchrony and diachrony in evolution 157
  3.3.2 The different ways of biology 160
  3.3.3 Levels of selection, group selection and semiosis 163
  3.3.4 Price’s equation approach to group selection 166
  3.3.5 Triadic analysis of groups 170

3.4 The causal structure of evolution 172
  3.4.1 The standard model of evolutionary causation 172
  3.4.2 Triadic analysis of biological information and the replicator 177
  3.4.3 Species, functions, groups 180
  3.4.4 Co-evolution of constraints and multi-level evolution 184
  3.4.5 Inclusive inheritance 186

3.5 Frequency dependency, complexity of adaptation and MEP 189
  3.5.1 Analytical primacy of frequency dependency in evolutionary theory 189
  3.5.2 Exaptation 193
  3.5.3 The Red Queen Principle 194
  3.5.4 Size, complexity and Maximum Entropy in evolution 198
  3.5.5 The Handicap Principle, size and metabolism 201

4. INDIVIDUALS 208

4.1 The methodological status of individualism and rationality in the evolutionary approach to economics 208
  4.1.1 Individualism, ‘methodological’ and evolutionary 208
  4.1.2 The tension between externalism and internalism in the economic theory of the individual 209
  4.1.3 Brains, minds and individuals 212
  4.1.4 Minds as systems of interpretance 216

4.2 Cooperation, energy and the evolution of the brain 218
  4.2.1 Brains as exaptatively emergent adaptations 218
  4.2.2 Signalling and brain evolution 221
  4.2.3 Enabling brains for living in groups 225
  4.2.4 Brain evolution, groups and energy 228

4.3 Brain semiosis, externalism and the emergence of group mindedness 232
  4.3.1 Connectionism 232
  4.3.2 Neuromemes and somatic markers 235
  4.3.3 Basic semiotic patterns of causation in the brain 237
  4.3.4 The naturalistic view on language 243

4.4 Dual selves, wants and needs 246
4.4.1 ‘Dual selves’ approaches in the neurosciences and economics 246
4.4.2 The semiotics of Acting Self and Object Self 249
4.4.3 Human choice and levels of evolution 251
4.4.4 Wants and needs 254

4.5 Identity 259
4.5.1 Personal and social identity 259
4.5.2 Identity and group markers 264
4.5.3 Emotions 266
4.5.4 Consumption, status and happiness 269

5. NETWORKS 275
5.1 Networks, individuals and signs 275
5.1.1 Networks, groups and distributed agency 275
5.1.2 Bimodality of networks 278
5.1.3 Causation and network structure: Methodological implications 283
5.2 Growth of information in evolving networks 286
5.2.1 Information, entropy and non-integral networks 286
5.2.2 Ascendancy and growth 290
5.3 Dimensions of evolving network structure 296
5.3.1 Transaction, communication, perception 296
5.3.2 Information externalities 300
5.3.3 Interaction costs and the emergence of hypercycles 302
5.3.4 Triadic view on network structure 305
5.4 Network structure and information diffusion in networks 308
5.4.1 Biological constraints on network evolution and group size 308
5.4.2 Group size and patterns of information diffusion 311
5.4.3 The in–group/out–group distinction 314
5.4.4 Imitation and frequency dependency of network processes 317
5.4.5 Human society 320
5.5 Trust, power and status 322
5.5.1 The trust dilemma in large groups 322
5.5.2 Capabilities and functions in network evolution 324
5.5.3 Power as foundational category in evolutionary network theory 328
5.5.4 Social capital 331
5.5.5 Status and frequency-dependent network dynamics 336

6. INSTITUTIONS 340
6.1 The multi-faceted nature of ‘institutions’ 340
6.1.1 Naturalizing institutions 340
6.1.2 Diverse approaches to institutions 343
6.1.3 Institutions as network regularities 347
Contents

6.1.4 Institutions and technology 348

6.2 Institutional semiosis:
   Emergence of institutions from networks 351
   6.2.1 The substantive view on institutions 351
   6.2.2 Institutional semiosis 354
   6.2.3 Induction and the primordial emergence of institutions 358
   6.2.4 Metaphors and hypercyclic abstraction of regularities 362
   6.2.5 Emergence of abstract rules as institutions 364

6.3 Institutions and cognition 366
   6.3.1 Institutions and language 366
   6.3.2 Status functions as metaphors 369
   6.3.3 Cognitive path dependence of institutions 372
   6.3.4 An impossibility theorem on institutional evolution 376

6.4 Performativity of institutions 378
   6.4.1 Performing institutions 378
   6.4.2 Case study: The emergence of early money 382
   6.4.3 Performativity of money 387
   6.4.4 Evolutionary microfoundations of the theory of institutions 390

6.5 Culture, cognition and the diversity of institutions 393
   6.5.1 Functional equivalence of different kinds of institutions 393
   6.5.2 A simple taxonomy of institutions 397
   6.5.3 Culture and institutional diversity: China and Europe 402

6.6 The evolution of power and the emergence of institutions 405
   6.6.1 The ‘specialization dilemma’ 405
   6.6.2 Power projection and scope of institutions 408
   6.6.3 Agriculture and formal institutionalization 411
   6.6.4 The biology of institutions 415
   6.6.5 The general evolutionary model of institutions 419

7. TECHNOLOGY 424

7.1 Technology and human nature 424
   7.1.1 Human niche construction by means of technology 424
   7.1.2 Technological evolution, human intentionality and alienation 426
   7.1.3 The analytical irrelevance of ‘consumption’ 429
   7.1.4 Technology and multi–level evolution 432

7.2 Technology as embodied knowledge 434
   7.2.1 Artefacts and actors 434
   7.2.2 Kinds of knowledge, design and technological functions 436
   7.2.3 Technological semiosis 439
   7.2.4 Routines 443

7.3 Evolutionary trajectories of technological creativity 447
7.3.1 Artefacts as replicators in technological evolution 447
7.3.2 The problem of technological taxonomy 448
7.3.3 Branching out of technologies 451
7.3.4 Technological creativity 455
7.3.5 Standardization and the evolving state space of technology 459

7.4 Technology, production and energy 463
7.4.1 Consumption as production 463
7.4.2 Technology and entropy 466
7.4.3 Hypercyclic leveraging of energy throughputs by technological evolution 469
7.4.4 The transition to agriculture 471
7.4.5 The modern carbon–based economy 474
7.4.6 Technology, energy transformations and MEP 478
7.4.7 The Anthropocene 482
7.4.8 The technosphere 485

7.5 Power and group selection of technology 488
7.5.1 The role of the military in technological innovation 488
7.5.2 Power projection and social organization of means of violence 491
7.5.3 Red Queen effects in institutional group selection 494
7.5.4 A natural experimentum crucis: China vs. Europe 497

8. MARKETS 504

8.1 Performing the artefact of markets in human networks 504
8.1.1 Markets as evolving networks 504
8.1.2 Performativity of economics and ‘marketization’ 507
8.1.3 Markets in the context of general evolution 510

8.2 Markets as institutions:
   Uncertainty and networked valuation 513
8.2.1 Trust and the asset specificity of specializing on market opportunity 513
8.2.2 The fundamental problem of the uncertainty of comparative advantage 517
8.2.3 Prices and market clearing 519
8.2.4 Asset valuation, markets and networks 522
8.2.5 The institutional nature of market valuation 526
8.2.6 Market states as institutions 530

8.3 Power and the institution of money 532
8.3.1 Money and credit 532
8.3.2 Government and trust into money 534
8.3.3 The institution of credit 538
8.3.4 Trust and status in monetary evolution 542

8.4 Prices as social facts 545
## Contents

8.4.1 The fundamental incompleteness of arbitrage 545  
8.4.2 The complexity of collective price-setting 547  
8.4.3 Reconsidering the simple supply and demand framework 550  
8.4.4 Market clearing across many markets: Macroeconomics 554

8.5 Transactional capabilities  
and firms as market replicators 558  
8.5.1 Social capital and transaction enabling transactions 558  
8.5.2 Dimensions of networks  
and scope of market transactions 560  
8.5.3 Firms, markets and networks 564

8.6 Firms, markets and human labour 571  
8.6.1 Firms and the measurement of entrepreneurial input 571  
8.6.2 Limitations to mobility of labour  
and corporate governance 573  
8.6.3 The performativity of incentive systems 576  
8.6.4 Fairness and wages as institutions 580

8.7 Markets and general evolution 584  
8.7.1 Money, credit and growth 584  
8.7.2 Market dynamics and entropic principles 587  
8.7.3 The growth of markets 591

References 596

Index 656