Contents

Preface		٧
---------	--	---

Part I	General principles of demoeconomics
1	The population-economy system —— 3
1.1	General characteristics of the population-economy system —— 3
1.2	Mathematical modeling of the PE system: specific features — 7
1.2.1	Principles of mathematical modeling —— 8
1.2.2	Nonlinear processes —— 9
1.2.3	Temporal hierarchy —— 9
1.2.4	Spatial hierarchy —— 10
1.3	Forecasting of demoeconomic development ——— 11
2	Probabilistic techniques in demoeconomic forecasting —— 16
2.1	Uncertainty in the PE system —— 16
2.2	Demoeconomic forecasting: the structure of probabilistic
	technique —— 19
Part II	Foundations of spatial demography
3	The population system —— 25
3.1	Key notions —— 25
3.2	State indicators of population —— 29
3.3	States evolution in a demographic process: general modeling
	principles —— 32
3.3.1	Structuring based on sex and space —— 33
3.3.2	Structuring based on sex, age and space —— 34
4	Demographic characteristics of fertility —— 36
4.1	Phenomenology of newborns distribution by maternal ages —— 36
4.2	Entropy model of age-specific fertility rate 39
4.3	Iterative method of age-specific fertility rate recovery —— 44
4.4	Dynamics of fertility rates —— 49
4.4.1	Dynamic model of total fertility rate —— 49
4.4.2	Dynamic model of age-specific fertility rate —— 57
5	Demographic characteristics of mortality —— 60

Phenomenology of mortality —— 60

Entropy model of sex-age distribution of mortality rate —— 62



5.1

5.2

5.2.1	Model construction —— 62
5.2.2	Model analysis —— 65
5.3	Parameter identification for the entropy model of mortality based on
	real data —— 67
5.4	Entropy decomposition of age-specific distribution of mortality by
	classes of diseases —— 76
5.5	Dynamic model of total mortality rate —— 82
6	Demographic characteristics of migration —— 87
6.1	General phenomenology of migration —— 88
6.2	Entropy-optimal distribution of migration flows —— 92
6.3	Optimality conditions for entropy models of migration —— 104
6.4	Parametric properties in entropy models of migration —— 108
6.4.1	Parametric properties of the <i>B</i> -model with complete consumption of resources —— 112
6.4.2	An example of analyzing the parametric properties of the B-model of
	migration flows —— 116
6.4.3	Parametric properties of the F -model with complete consumption of
	resources —— 126
7	Macrosystem models of population dynamics —— 132
7.1	Dynamics of isolated population —— 132
7.1.1	Deterministic functions of fertility and mortality —— 132
7.1.2	Random functions of fertility and mortality —— 139
7.2	Macrosystem dynamic model with linear reproduction of population and
	balanced emigration —— 142
7.2.1	Stationary states —— 144
7.2.2	Stability of stationary states —— 147
7.3	Stable stationary states of spatial distribution of population: an
	example of scenario forecasting —— 153
7.4	General macrosystem model of population size dynamics —— 157
7.4.1	Stationary states —— 161
7.4.2	Stability of stationary states —— 162
Part III	Foundations of spatial economics
8	Modeling economics —— 169
8.1	Political economy, micro- and macroeconomics, mathematical
	economics: objects and goals —— 170
8.2	Behavioral models for economic agents —— 176
8.2.1	Models of rational behavior —— 177

x --- Contents

8.2.2	Models of compromise behavior —— 180
8.2.3	Models of stochastic behavior —— 187
9	Evolutionary economics —— 191
9.1	General principles of evolutionary economics —— 191
9.2	Market equilibrium and stability —— 192
9.3	Innovation activity of economic agents —— 196
9.3.1	External investments —— 199
9.3.2	Internal investments —— 202
9.4	Economic growth —— 206
10	Self-organization in economic systems —— 211
10.1	General notions —— 211
10.2	Phenomenology of the model of competitive firms. Determination of transitions —— 213
10.3	
10.3 10.4	Construction of utility functions. Evaluation of transition rates —— 217
10.4	Equations of the model. Stationary states —— 220 Stability of stationary states —— 226
10.5	Stability of Stationary States —— 226
11	Spatial interaction of economic systems —— 232
11.1	Entropy model of spatial economic interaction —— 232
11.2	Economic system with triangular spatial structure —— 243
12	Selected models of spatial macroeconomics —— 248
12.1	Entropy decomposition —— 248
12.2	Spatial interaction of economic clusters —— 256
12.2.1	Static interaction —— 258
12.2.2	Dynamic interaction —— 261
12.3	Model of economic systems exchanging investments —— 264
12.3.1	Singular stationary states —— 267
12.3.2	Stability of singular stationary states —— 269
13	Fluctuations in models of spatial economics —— 281
13.1	Downturns and upturns in economic activity —— 281
13.2	The immersion method for periodic solutions —— 282
13.3	Periodic solutions to generating system: application of the Laplace
	transform —— 286
Part IV	Macrosystem models of demoeconomics
14	Macrosystems concept in demoeconomics —— 299
14.1	Phenomenology of demoeconomics —— 299

xii	 Co	n	t۵	nts	
AII	 L.U	ш	ιe	1115	

14.1.1	The systems character of demoeconomic processes —— 300
14.1.2	The individual and the collective —— 301
14.1.3	Time scales —— 301
14.2	Macrosystems concept of demoeconomics: model representation —— 303
14.3	The Monte Carlo method in probabilistic macrosystem modeling of demoeconomic processes —— 305
15	One-sector macrosystem demoeconomic model (MSDEM) —— 310
15.1	Structure and basic variables of the model —— 310
15.2	Equations of one-sector MSDEM —— 313
15.2.1	The block $1sEM$ —— 313
15.2.2	The block MSDM —— 316
15.3	An example of one-sector MSDEM —— 320
15.3.1	Equations of the model —— 321
15.3.2	Analytic treatment of the simplified one-sector MSDEM —— 324
15.3.3	Computer experiments with the one-sector MSDEM —— 327
15.3.4	Analytic treatment and computer experiments with the one-sector
	PMSDEM —— 333
16	Macrosystem demoeconomic model with regional localization of sectors (branches) $Ns - MSDEM \longrightarrow 339$
16.1	Structure and basic variables of the model —— 339
16.2	Equations of $Ns-MSDEM$ with resource exchange on regional
	markets —— 344
16.2.1	The block NsEM —— 344
16.2.2	The block MSDM —— 349
16.2.3	The block TRM —— 351
16.3	An example of analytic treatment of $Ns - MSDEM \longrightarrow 352$
16.3.1	Equations of the model —— 352
16.3.2	Stationary states —— 354
16.4	Computer analysis of Ns – MSDEM —— 358
16.4.1	Equations of the model —— 358
17	Macrosystem model of labour market —— 371
17.1	Quantitative state indicators of labour market 371
17.2	Structure and equations of the model 373
17.3	Competition among cohorts —— 375
17.3.1	Intrinsic competitive ability —— 376
17.3.2	The comparative competitive ability —— 379
17.3.3	Labour force requirement and supply of labour force —— 380

17.4	Identification algorithm for model parameters —— 381
17.5	Identification of model parameters based on real data —— 383
18	Probabilistic macrosystem demoeconomic model —— 392
18.1	Aggregated structure of PMSDEM and its spatiotemporal
	characteristics —— 392
18.2	Realization of <i>PMSDEM</i> : the Monte Carlo methods —— 397
18.2.1	Average computing —— 397
18.2.2	Random search —— 398
18.2.3	Generation of random variables with given properties —— 399
18.3	The POPULATION block —— 400
18.3.1	Classification of population —— 400
18.3.2	Biological reproduction of population (the R module) —— 402
18.3.3	Migration (the M module) —— 405
18.3.4	Dynamics of population (the DP module) —— 411
18.3.5	Outputs of the POPULATION block —— 411
18.4	The economy block —— 412
18.4.1	Production economy (the PE module) —— 412
18.4.2	Exchange of products (the Ex module) —— 416
18.4.3	Prices (the <i>Pr</i> module) —— 418
18.4.4	The output variable of the ECONOMY block —— 420
18.5	The interaction block —— 421
18.5.1	Migration (the MPP module) —— 421
18.5.2	Fertility (the TFR module and the $ASFR$ module) —— 425
18.5.3	Mortality (the TMR module and the $ASMR$ module) —— 431
Part V	Mathematical appendices
A	Some theorems of implicit functions —— 441
A.1	Introduction —— 441
A.2	Local properties —— 441
A.2.1	Existence and continuity —— 441
A.2.2	Homogeneous forms and posinomials —— 443
A.2.3	Differentiability —— 447
A.3	Global properties —— 450
A.3.1	Existence. —— 450
A.3.2	Differentiability —— 453
В	Estimating the local Lipschitz Constant of the entropy operator $B_{v,q}$ —— 454
B.1	Introduction —— 454
B.2	Definitions —— 454

B.2.1	The operator $B_{\mathbf{v},\mathbf{q}}$ —— 454
B.2.2	The normal operator $B_{\nu,q}^0$ —— 455
B.2.3	The relation between $B_{ u,\mathbf{q}}^{0}$ and $B_{ u,\mathbf{q}}^{0}$ —— 455
B.3	Properties of the entropy operator $B_{\nu,q}^0$ —— 457
B.3.1	Existence and uniqueness —— 457
B.3.2	Majorant construction —— 459
B.4	Estimating the norm of derivative of the entropy operator $B_{\nu,\mathbf{q}}^0$ —— 461
B.5	Estimating the spectral norm of the matrix $[\Gamma_{\lambda}^0]^{-1}$ —— 464
c	Estimating the local Lipschitz Constant of the entropy
	operator $F_{\nu,q}$ —— 467
C.1	Definitions —— 467
C.2	Properties of the normal entropy operator $F_{v,\mathbf{q}}^0$ —— 468
C.3	Majorants of the operator $F_{\mathbf{v},\mathbf{q}}^0$ —— 470
C.4	Estimate l^F —— 473
D	Zero-order multiplicative algorithms for positive solutions to nonlinear
	equations —— 475
D.1	Introduction —— 475
D.2	Auxiliary estimates —— 476
D.3	Convergence analysis by continuous analogs of iterative
	algorithms —— 479
D.4	Convergence of zero-order multiplicative algorithms with m -active
	variables: nonlinear equations —— 480
D.5	Convergence of zero-order multiplicative algorithms with m -active
	variables: convex programming —— 482
E	Multiplicative algorithms for positive solutions to entropy-quadratic
	programming problems —— 489
E.1	Problem statement —— 489
E.2	Optimality conditions —— 490
E.3	Multiplicative algorithm —— 492
Bibliog	graphy —— 493

xiv — Contents

Index —— 498