## Index

*a priori* theory 306  
Abu Dhabi 232  
ACROPOLIS 31  
AENP 52  
Africa 54–5  
agency costs 289–91  
*Agenda 21* 123, 124, 359, 374, 375  
agriculture  
  industrial-type 105  
  intensification 94–6  
  sustainability indicators 11  
see also dynamic system models in agriculture  
Albania 233, 234  
Americas 54–5  
analytic hierarchy process (AHP) 167, 172–3, 176, 368  
apologists 32–3  
aquaculture: environmental  
  externalities and common-pool resources 277–97, 371–2  
agency costs 289–90  
artificial or augmented natural wetlands 286, 296  
biodiversity loss 287  
common-pool resources 286–7  
consequential impacts 289–91  
emission taxes 288–9, 293  
environmental spillovers 288–91, 296–7, 371–2  
agency and transaction costs 290–91  
as source of inferior sustainability outcomes 280–86  
genetically modified tilapia fish 287  
intensive or extensive aquaculture 282  
lack of sustainability in absence of market factors 278–80  
market failures 280–81  
net income path 278–80  
pollution 296  
pollution rights or environmental use rights 288–9, 293–4  
polyculture 286  
poverty or low-income trap 287  
pricing and market-making approaches 291–4  
private property rights 290, 293–4  
prohibitions and administrative-type regulations 289, 294–5  
socioeconomic change 287  
subsidies 293  
taxes or charges 293  
transaction costs 289–91  
unfavourable externalities 280–81  
unsustainable income paths 279, 281  
Armenia 233  
Asian nations 33, 54–5, 218, 224, 278  
atmospheric general circulation models (AGCM) 22  
atmospheric ocean general circulation models (AOGCM) 22  
Australia 10, 367  
dynamic modelling 26  
forage shrubs in dryland agricultural systems 12  
input–output modelling 24  
land and water management 223, 229, 231, 232–3  
unsustainable and sustainable trajectories 26  
see also decision-support systems (DSS) for environmental disaster planning  
Austria 220, 223, 224, 233  
Bangladesh 282, 326  
Barometer of Sustainability 52, 54  
BASIC language 18  
Bayesian decision theory 11  
Belgium 223–4, 225, 226–7  
benchmarking analysis 149, 153, 155  
biocapacity 49  
biodiversity changes 93, 94–7, 287
Blueprint scenario 28, 29
bounds of the ecologically possible 46
brainstorming 129, 136
electronic 127
solo 124, 125–6, 127, 128–9, 138
Brazil 5
Brundtland Report see Our Common Future
Bulgaria 219, 225, 226, 233
business as usual (BAU) scenario 28, 29, 31
agriculture 259, 261, 262, 263, 265, 268–9
C40 Cities Climate Leadership Group 5
Canada 8, 220
land and water management 223, 224, 228, 231, 232
utility planning 163
Water Act 218
capital 42, 65–6, 74
accumulation 62–3, 70, 84
accumulation equation 64, 65, 67–8
depreciation 67
growth equation 74–5
manufactured 41–2
natural 40, 42, 46, 47
social 41–2
stock 65–6, 70, 75–6
capital–output ratio 70–71, 72, 77
carbon dioxide emissions 5, 8, 22–3, 361
see also resources, pollution and sustainable development policies
carbon footprint 21
case studies 10–12, 13
causal relation equation 64
cause–effect relationships 184, 249
Central and Eastern Europe 219, 225, 227, 235–6, 238, 239
CERES 155
certification schemes 113
chemical wastes 86
China 5, 55
aquaculture 277
genetically modified organisms 95, 97–9, 102, 113
infrastructure 324
choice (decision-making) 5
civil society 375, 377
class diagrams 318
cognitive maps 308
common-pool resources see under aquaculture
composite indicator 47
conceptual models 8–10, 12, 13
contingent valuation methods 295
cost-benefit analysis 9, 14, 163, 295
creative decision-support systems (CDSS) 40, 367
see also decision-support systems (DSS) for environmental disaster planning
critical threshold values 11
Croatia 226, 232, 233
cross-efficiency see data envelopment analysis (DEA) for ecoefficiency evaluation
Czech Republic 219, 223, 224, 226, 227, 228, 233
Daly’s triangle framework 40–43
data envelopment analysis (DEA) for ecoefficiency evaluation 141–56, 367–8
aggressive cross-efficiency (AXEF) 145, 150–52, 154
BCC model 142, 144, 147, 150–51
BTUs 149
CCR model 142, 143–5, 147, 149, 150–51
cross-efficiency models 144–6
decision-making unit (DMU) 143–5, 150–52, 153, 154
discriminatory models 146–7
environmental input and output factors 147–54
data and model 147–9
environmental indicators 148
practice and application 153–4
research and results 149–52
expansion of ecoefficiency to sustain efficiency 154–5
generalized Tchebycheff radius of classification preservation (GTR) model 146–7, 150–52, 154
labour input 149
literature review 141–2
output, desirable and undesirable 148
performance metrics 152
reduced CCR (RCCR) formulation 146–7, 150–52, 154
simple cross-efficiency (SXEf) 145, 150–51, 154
technical and scale efficiency models, ratio-based 143–4
data-driven models 306
database modelling 18, 19
DEARS model 31
decision conferencing approach 378
decision rules 184
decision-support systems (DSS) 6–7, 8, 9, 13, 18, 19, 25
group 125
mining 162, 173
multicriteria 25
decision-support systems (DSS) for ecosystems management: Singerian approach to urban infrastructure decision-making in Houston, United States 303–320, 372–3
aesthetic perspective 307–8, 316
built domain 309
capital improvement plan (CIP) 311–13
Courtney’s decision-making model 308, 314, 317, 319
cultural factors 316
development 318–19
economic factors 303–304, 310, 314–15, 316, 317
environmental factors 303–304, 310, 313–15, 316, 317, 320
ethical perspective 307–8, 316, 318
expanded decision-making paradigm 307
geographic information system (GIS) 310, 313, 318
human domain 309
individual perspective 306, 310–311, 314–15, 318
information management system (IMS) 310, 313
multiple organizational perspective 305, 314, 315, 317
natural domain 309
need category 314–15, 317
personal perspective 306, 307, 318
political perspective 304, 314–15, 316, 317
Singerian inquiry 304–8
social perspective 303–304, 306, 316, 317
technical perspective 307, 308, 310, 314–15, 316, 318
transportation issues 310
unbounded systems thinking (UST) 305–6, 308, 317, 318, 319
unified modelling language (UML) 308, 311–13
decision-support systems (DSS) for environmental disaster planning 123–39, 367
creative decision-support system (CDSS) 125–6, 128, 129–38
abstracts 128, 132
analysis 130–31
brainstorming 129, 136
creativity and innovation 137, 139
decision-makers (DMs) 129
disaster planning scenario 130
evaluation apprehension 137
experts’ classifications 133–4
external information 128
housekeeping process 137
implications for theory and practice 137
individual performance 131–2
issue list 130–31
lateral thinking 128–9
nominal group performance 132–7, 139
optimum number of people needed in a group 134, 135
output 129
production blocking 137
productivity levels 133, 135, 136
reading and editing 128–9
recommendations for future study 138
issue identification framework 126–9, 137
solo brainstorming technique 128–9, 138
decision-support tools 3–15, 360
research methodology 5–7
model and decision support categories 6–7
research categories 6
sample 5–6
results and analysis 7–14
context of sustainability 7–14
extent 14
modelling type 14
outcomes 14
research type 7
see also decision-support systems (DSS)
Denmark 223, 226, 233, 292
depreciation dumping 82–3
design (decision-making) 5
developing countries see infrastructure development as policy lever in developing countries
dialectic approach 306
discriminatory models 146–7
Doyle and Green formulation 145
DP Simone models 45
dynamic general disequilibrium 189
dynamic modelling 24–7, 28, 29, 34,
361
simulation 29, 31
see also dynamic system models in agriculture; system dynamics (SD) modelling
dynamic system models in agriculture: Huerta de Murcia, Spain 245–74,
370–71
abandonment rate 258
actual and expected values of traditional irrigated land 263
actual trend scenario 262–8, 269
area of traditional irrigated lands 255, 259–62, 264, 265, 269
average size per farm 255, 257,
258–9, 261, 265–6, 268, 269
base trend scenario (business as usual scenario) 259, 261, 262,
263, 265, 268–9
conservation policy scenario 259,
261, 265, 269
immigration rate 265
land demand control scenario 259,
261, 268
landowners, number of 255, 257,
260–61, 265–6, 268, 269
methodological approach 248–9,
250
model testing 251–4
goodness of fit (Theil statistics) 254
Monte Carlo simulation response to combined changes in model parameters 253
sensitivity analysis 252–3
stock-and-flow diagram 252
structural tests 251
model variables and parameters 273–4
municipal land planning policies 262, 264–5, 268, 269
population 255–6, 259, 264–5, 267,
268, 269
profitability 255–6, 258–9, 261
scenario analysis 259–62
simulation results 254–9
Water Authority 259
water deficit 258–9, 268
Water Office 262, 268
water pollution 258–9, 265, 268, 269
Water Quality Index 254, 255,
258–9, 265, 267, 268, 269
water resources for irrigation 264
water volume from Tagus-Segura water transfer 264
DYNAMO Compiler 61–2
Earth Summit (Rio 1992) 66, 123
Easter Island 62
ecoefficiency evaluation see data envelopment analysis (DEA) for ecoefficiency evaluation ecological aspects of sustainable development 24, 45, 51, 248, 297,
368, 374
ecofidence loop 88
Ecological Footprint (EF) 21–2, 23–4,
48–9, 51–2, 56, 57, 361
ecological indicators 46, 47
ecological modelling 9
ecological optimization method 8
ecological productivity 87
Index 385

ecological reproducibility 81–5, 86, 87, 363–4
steady-state equilibrium 83–5
ecological sensitivity simulation of population 88
ecological services 54
ecological stress 56
ecological sustainability and project appraisal 8
ecological well-being 27, 39, 44
ecology see genetically modified organisms (GMOs), economics and ecology
econometric models 18, 19
economic agents 375, 377
economic dimension of sustainable development 24, 45, 51, 297, 368, 374, 377
agriculture 248
mining 167, 170, 173, 175
see also triple-bottom-line methods
economic growth simulations 65, 68–9
economic indicators 46, 47
economic trap 89, 363
economic well-being 44
economics see genetically modified organisms (GMOs), economics and ecology
ecosystem models 9
ecosystem stress 54, 55
Ecosystem Wellbeing Index (EWI) 52, 53–5
ecosystems management (EM) 372–3
see also decision-support systems (DSS) for ecosystems management
emission taxes 288–9, 293
employment status indicator (ESI) 51
Energy and Environmental Prediction (EEP) model 11
energy policies see resources, pollution and sustainable energy policies in Pakistan
energy use at urban scale 11
enhanced carrying capacity options (ECCO) model 26, 28
enterprise model 314
entropy-maximizing methods 18, 19
environment and economy integration 9
environmental assessment (EA) 24, 57
environmental charges 10
environmental dimension of sustainable development 167, 175, 370, 377
see also triple-bottom-line methods
environmental externalities see aquaculture: environmental externalities and common-pool resources
environmental impact assessment 166
environmental indicators 47
environmental information system framework 8
environmental input and output factors see under data envelopment analysis (DEA)
environmental management plans (EMPs) 165–6
environmental modelling 370–71
environmental paradox 39, 52–6, 362
environmental performance indicators (EPI) 147
environmental quality management 8
environmental response models 370
environmental spillovers see under aquaculture
environmentalists 375, 377
equilibrium condition 62–3
see also general equilibrium; steady-state equilibrium
Estonia 226
Europe 34, 54–6, 292
see also modelling sustainable water prices in Europe
European Commission 246
European Union 22
evolutionary theories 376
‘expert choice’ 173
feasibility study 167
feedback loop 64–5, 87
agriculture 249, 255
energy management 184
negative 18, 64, 79, 86, 249
non-renewable resource availability 71–2, 77
positive 18, 64, 249, 255, 258
social 25, 77–80
Finland 223, 226, 232, 233
fiscal incentives and industrial pollution 8
five-capital model 42
formal logic concepts 306
FORTRAN language 18
frameworks for sustainable development 8, 9–11, 13
France 13, 218, 223, 226–7, 233
FROG (First Raise Our Growth) scenario 28, 31
Frontier Analyst 142
future research 32–4
fuzzy logic 378

general efficiency measure 143
general equilibrium models 19, 182
genetically modified organisms (GMOs), economics and ecology 91–115, 364–6
coevolution, lack of 112
ecological issues 93–9
biodiversity change, long-term 94–7
evolution and erosion of attributes 97
hypothetical types of potential changes in stock once successfully adopted for sufficient period of time 96
interspecies competition as negative consequence 98–9
selective breeding 99
trade-offs between attributes 97–8
economics of development and marketing 102–111
economic theory providing support for propositions 106–111
general influences 102–6
market and profitability 106
overhead costs and development 108
patterns of development by private enterprises 105
profitability and demand 109
profitability and farm size 110
patent walls 111–12
risks and uncertainty 99–102
legal liability 102

precautionary principle 100–101
social criterion 101
social conflicts and knowledge imperfections 113–15
genetically modified tilapia fish 287
genuine progress indicator (GPI) 50, 52
Genuine Savings Index 46, 48, 57
GEO4 30, 31
geographical information system (GIS)
-based decision-support system (DSS) 11, 310, 313, 318
-based energy and environment prediction model 11
geographical scales, models and associated data sets 21
Geopolity scenario 29, 31
Germany 13, 114
land and water management 218, 219, 223, 224, 225, 226, 233
GINFORS model 22
global environmental outlook 30, 31
global resource accounting model (GRAM) 22
global warming and climate change 30, 31
GMOs see genetically modified organisms
golden rule of capital accumulation 80–81
goodness of fit (Theil statistics) 254
governance 375
Greece 223, 224, 229
Sporades islands 25–6, 27
greenhouse gas emission scenarios 30, 31
see also carbon dioxide emissions
growth paths 78
GS 51, 56, 57
happiness indicators 34
headline indicators 44
hedonic price model 10
Hegelian model 306
hierarchical framework for evaluation of mine projects in India 161–76, 368
Air (Prevention & Control of Pollution) Act (1981) 165
analytic hierarchy process (AHP) 167, 172–3, 176, 368
case application 170–76
composite priority weights of mine projects as per corporate executive 174, 175
data collection 173–4
mine projects under evaluation 171–2
model 169
model formulation 172–3
results and analyses 174–6
sensitivity graph of loss of farmland 176
sustainable factors incorporation 173, 175
Coal India Limited (CIL) 170–71, 173
comprehensive framework 167–70
Environment (Protection) Act (1986) 165
Environment Statement 165
environmental dimension 175
environmental management plans (EMPs) 165–6
farmland, loss of 175–6
Forest (Conservation) Act (1980) 165
internal and external impacts 167, 172, 173, 174, 175
Mine Projects Evaluation 173
Mines and Minerals (Regulations & Development) Act (1987) 165
mining 167–8
Ministry of Coal 171
Ministry of Environment and Forests (MoEF) 165–6
National Environment Tribunal Act (1991) 165
nationalization 164
noise level impact 175
physical, economic and social dimensions 167, 170, 173, 175
Public Liability Insurance Act (1991) 165
rehabilitation and resettlement programmes 166
State Pollution Control Board (SPCB) 165
Statement of Industrial Policy 165
sustainability in coal sector 165–6
sustainable development at macro level 162
sustainable development at micro level 163
water contamination impact 175
Water (Prevention & Control of Pollution) Act (1974) 165
Water (Prevention & Control of Pollution) Cess Act (1977) 165
historical fit of models 189
Human Appropriation of Natural Capital (HANC) 49
Human Appropriation of Net Natural Product (HANPP) 48, 49, 52, 57
human capital 42
Human Development Index (HDI) 50, 52, 56, 57–8, 362
Human Wellbeing Index (HWI) 52, 53–6, 362
Hungary 219, 223, 224, 225, 226–7, 228, 233
I-PAT 48
Iceland 223
ideologies 32–4, 42
IFS dynamic simulation model 29, 31
IMAGE integrated model 31
independent reporting 127
Index of Sustainable Economic Welfare (ISEW) 50, 52
India 55, 218, 286, 324
see also hierarchical framework for mine project evaluation
indicators see measurement and indicators of sustainable development
Indonesia 324, 326
industrial wastes 82–3
information management system (IMS) 310, 313
infrastructure see decision-support systems (DSS) for ecosystems management; infrastructure development as policy lever in developing countries
infrastructure development as policy lever in developing countries 322–53, 373–4
alternative policy combinations without increasing infrastructure development 349–51
capital owned by capitalist sector 341, 346–7, 350
capital–worker ratio in capitalist sector 327, 341, 346–7, 350
coop eratives for self-employed sector 339, 341, 342–3, 352
economic growth patterns and infrastructure performance 323–35, 339
wage employed labour in workforce in selected Asian countries 326
feudalism 335
financial institutions development 339, 341, 343
financial institutions development, infrastructure services improvement and cooperatives for self-employed sector 350
fraction revenue to capitalist sector 341, 346–7, 350
indicators for policy evaluation 339
individual policy instruments 340–44
infrastructure investment 340, 341, 342
infrastructure investment and financial institutions development 345, 346, 348
infrastruc ture investment and infrastructure services improvement for self-employed sector 345, 346
infrastructure investment, infrastructure services improvement and taxing unearned income for self-employed sector 347, 348
infrastructure investment for self-employed sector 341, 342
infrastructure investment and taxing unearned income 346, 348
infrastructure investment, taxing unearned income and financial institutions development 347, 348–9
infrastruc ture investment, taxing unearned income, financial institutions development, cooperatives and infrastructure services improvement for self-employed sector 347, 349
performance of individual policy instruments 341
policy combinations incorporating increased investment 344–9
privatization 352
production in capitalist sector 341, 346–7, 350
production facilitation 373
production infrastructure facility level 341, 346–7, 350
production in self-employed sector 341, 346–7, 350
production, total 339, 341, 346–7, 350
rent burden of self-employed sector 341, 346–7, 350
resource allocation by government 373
simulation experiments to test model behaviour against historical experience in dual economy 335–8
taxing unearned income 339, 343–4, 352
taxing unearned income but equal access to infrastructure 341	
taxing unearned income but unequal access to infrastructure 341
taxing unearned income, infrastructure services improvement, financial institutions development and cooperatives for self-employed sector 350
taxing unearned income, infrastructure services improvement and financial services development for self-employed sector 350
taxing unearned income and infrastructure services improvement for self-employed sector 350
transportation facility level 341, 346–7, 350
transportation infrastructure 373
urban-rural duality 326
wage rate 341, 346–7, 350
see also system dynamics (SD) modelling in dual economy
input–output modelling 9, 17–34, 360–61
carbon dioxide emissions 22–3
ecological footprint and material flow analysis 23–4
geographical scales, models and associated data sets 21
triple-bottom-line methods 24
see also dynamic modelling
integrated models 10, 11, 31, 182
intellectual property rights 103
intergenerational equity 162
intermediate means to intermediate ends 41–2
international futures (IF) model 28
Ireland 223
Israel 231
Italy 220, 223, 224, 225, 226–7, 233
Japan 220, 223, 224, 327
Jazz scenario 29, 31
Jordan 232
Kantian model 306
Kenya 26
KJ method 127
Korea 223, 224, 326, 327
Kruskal-Wallis rank test 152
Kyoto commitments 31, 217
land and water resource management see modelling sustainable water prices in Europe
legal liability 114
Leibnizian model 306
less developed countries 111–12
limits to growth models 25, 28
linear programming input–output analysis 13
linear programming optimization 142
Lisbon strategy 217
Lithuania 225, 227
Living Planet Index (LPI) 48, 49, 57
Lockean model 306
lucky growth paths with ecological feedback 89
Luxembourg 223, 229
MA ecosystem analysis 54
macro-level option generator 10
macro-level sustainable development 8, 9, 14, 162, 176, 284
macroeconomic growth models 9, 14, 25, 62–3, 64, 66
magnitudes of objective values 147
Malaysia 326
management, long-term 70
Mann-Whitney U-test 152
‘master equations’ 49
Material Flow Analysis (MFA) 23–4, 48, 361
Mauritius 26
MDESRAP (model for dynamics of electricity supply, resources and pollution) see under resources, pollution and sustainable energy policies
mean absolute proportion error (MAPE) 254
mean-squared error (MSE) 186, 189–92
measurement and indicators of sustainable development 39–58, 147, 361–2
definitions and Daly’s triangle framework 40–43
environmental paradox and well-being 52–6
happiness indicator 34
importance 43–52
composite indicator 47
economic (manufactured and financial capital) indicators 46, 47
employment status 51
environmental/ecological indicators (natural capital) 46, 47, 147
genuine progress 50, 52
good indicators 44
headline indicator 44
preliminary results 51–2
qualities of good indicators 45
social indicator 46
sociopolitical (human and social
capital) indicators 47
typology of indicators 44–51
lessons learnt and future
developments 56–8
see also well-being indicators
mental model 314
Mexico 223
micro-level sustainable development
166, 167, 176, 284
Millennium Ecosystem Analysis 52
mining see hierarchical framework for
evaluation of mine projects in
India
mixed modelling 14
model of an integrated dryland
agricultural system (MIDAS) 12
modelling
dynamic see dynamic modelling
ideologies and future research 32–4
scenarios see scenarios
system dynamics see system
dynamics modelling
typology 17–20
classification with advantages and
limitations 19
see also modelling long-term
sustainability; modelling
sustainable water prices in
Europe
modelling long-term sustainability
61–90, 362–4
birth rate 87
death rate 79
ecological productivity 87
ecological reproducibility see
ecological reproducibility
ecological sensitivity simulation of
population 88
economic growth simulations 65, 78
lucky growth paths with ecological
feedback 89
macroeconomic growth model 62–3,
64, 66
physical reproducibility see physical
reproducibility
productivity 77
simulations for sustainable growth
85–9
social reproducibility see social
reproducibility
steady-state equilibrium 65
substitutes for non-renewable
resources, growth paths for 86
system dynamics (SD) modelling
and feedback loop 64–5
unknown variables and constants
63, 67, 69, 73, 80, 82
modelling sustainable water prices in
Europe 12, 215–39, 369
agriculture 218
annual river flows, long-term 218
average sale of water 236–7
consumption and price relationship
230–31
consumption of water in selected
countries 219
cost and production of water 231,
233–4, 236, 237
drought 218
economic development 217–18
empirical evidence of existing
relations 236–8
energy production 218
European Community programme
216
glacial melting 218
household use 219–20
irrigation 217
leakages 233–4, 237, 238
metering 220–22, 225, 228–30, 238
natural water storage capacity 218
operation and maintenance costs
225
population growth 217–18
price changes 238–9
relationships applied in the model
230–36
creation of values of water prices
236
leakages of water 233
price elasticity of water demand
for domestic consumers 232–3
Sustainable Development Strategy
(SDS) 216–17
tariffs 220–22, 224, 227, 234–5
block 222–3, 225
social or conservation 222–4
specification 222
water charges 220–28
annual water charges in relation to
gDP per capita 227
categories of prices in OECD
countries 223
prices and annual expenditure on
water 226
Water Framework Directive (WFD) 215, 218, 221
water-efficient devices 238
Moldova 233
monetary input-output tables (MIOT) 24
monopoly price 103, 107–8
Monte Carlo simulation 88, 253
MOSUS project 22, 27
multi-party value theory 8
multicriteria models 8, 11, 163
multidimensional evaluation method
11
multifactor models 142
multifactor productivity ratio 148–9
multiple attribute decision-making
(MADM) methods 12
multiple criteria decision-making
analysis (MCDA) 12, 14, 377
multiple goal linear programme 13
multiple objective decision support
tool of agroecosystem
management (MODM) 13
multiple objectives 377, 378
multiple perspectives 306
multiple regression 152
multiple stakeholders 377
multivariate approaches 51
multivariate sensitivity simulation 88
mutually assured destruction (MAD)
scenarios 28
narrative in scenarios 27, 29, 30
natural systems 40–41, 43
neoclassical golden rule 74–6
Nepal 326
Netherlands 10, 13, 223, 226
New Zealand 23, 28, 30, 223
non-governmental organizations 375
non-linearities 184
non-parametric tools 152, 155
non-renewable resource availability
69–70, 71–2, 74, 77, 85, 87, 363
see also substitutes
Norway 223, 225, 226, 227
OECD countries 45, 223, 224–5, 228
‘One Planet Living’ (OPL) 21
optimization model and techniques s
8, 14, 18, 19
Our Common Future (Brundtland
Report) 3, 4, 32, 359
environmental management 123
land and water management 216,
217
measurements and indicators 39,
46, 48
mining 167
output 65–6, 67, 70, 72, 75–6, 85, 87
output–labour ratio 77
output–substitutes ratio 88
Pacific countries 54–5, 56
Pakistan 324, 327
see also resources, pollution and
sustainable energy policies
patents 102–3
percent error in variations 188–9
performance evaluation 153
Philippines 324, 326
physical dimension of sustainable
development 167–8, 170, 368
mining 167, 170, 173, 175
physical input–output tables (PIOT)
24
physical reproducibility 65–72, 79, 363
capital depreciation 67
capital–output ratio 72
economic growth simulations 68–9
feedback loop for non-renewable
resource availability 71–2
non-renewable resource availability
69–70
simulations for sustainability 70–71
steady-state equilibrium 67–8
sustainability 65–7
Poland 218–19, 223, 224, 225, 226,
228, 236
Collective Water Supply and Sewage
Collection Act 227
Ministry of Housing, Construction and Development 220
Polestar 30, 31
policy levers see infrastructure development as policy lever in developing countries
polluter pays principle 215
pollution see resources, pollution and sustainable energy policies in Pakistan; water pollution
population growth 74, 76, 85, 88, 162
agriculture in Spain 255–6, 259, 264–5, 267, 268, 269
ecological sensitivity simulation 88
equation 72
Portugal 223, 224, 226–7, 233
poverty and deprivation elimination 162
poverty or low-income trap 287
POWERSIM software 62, 183, 368
pressure–state–response (PSR) model 45
price discrimination theory 104
prisoner’s dilemma 281
production feedback equation 87
production function 62–3, 74
productivity 77, 85
ecological 87
models 143
reduction 70
project appraisal tool 163
proof, adequacy of 114
qualitative framework and modelling 5, 8, 10, 11, 13, 14, 377
quality of life 50
quantitative modelling 6, 8–13, 14, 27, 314, 377
radicals 34
ratio-based technical models 143–4
raw material input rate 70
Red List of Threatened Mediterranean Landscapes 270
reformists 33–4
regime analysis 11
regional development scenarios for sustainability 11
regional sustainability assessment 11
regression models 152, 155
renewable sources availability 83, 87
reproducibility see ecological; physical; social
research categories 359–60
resource energy and analysis package (REAP) 23–4
resources, pollution and sustainable energy policies in Pakistan 181–211, 368–9
capital sector 185–6
carbon dioxide emissions 196, 198–200, 202, 205, 207–208, 210
carbon dioxide intensity 189–90, 192–3
carbon dioxide tax 197, 207
costs and pricing sector 185
economic growth and energy policies 206–207
electricity demand sector 184, 185
electricity production 189–93
electricity supply 194–5
electricity consumption sector 206–207
environment sector 185–6
environment-oriented scenario 207
gas-based electricity generation 194–5, 200, 202–5, 208, 209
hydropower sector 184, 185
hydro-based electricity generation 194–5, 197, 200, 201–5, 207–208, 209–210
independent power producers (IPPs) 181, 185, 195, 196, 202–203, 207, 209
investment sector 184–5
MDESRAP (model for dynamics of electricity supply, resources and pollution) 183–93, 368
approach 183–4
behaviour of model 186
structure of model 184–6
validation 186–93
architecture 187
behaviour validity 188–9
error analysis of model 191
error in carbon dioxide intensity 192
error in electricity production 191
simulated and historic carbon dioxide intensity 190
simulated and historic electricity generation 190
simulated and historic energy intensity 189
structural validity 186–8
structures adopted from existing work 188
Theil's inequality statistics 189–93
oil-based electricity generation and oil imports dependence 194–5, 197, 200, 204–205, 207, 209
policy analysis 193–209
alternative policy design 196
base case policy 194–6
carbon dioxide emissions 196
comparison of cumulative capacity mix 194
electricity supply 194–5
environment-oriented policy mix 196–201
capacity mix 199
cumulative oil imports 200
electricity intensity 198
electricity price 201
emissions 199
percentage losses of GDP 200
price 197
scenario results 198
market-oriented policy mix 201–204
capacity mix 202, 204
carbon dioxide emissions 202
cumulative oil imports 203
percentage losses in GDP 203
resource import dependence 195
self-oriented policy mix 204–209
carbon dioxide emissions and energy policies 207–209
carbon dioxide emissions under alternative scenarios 208
cumulative oil imports 205
economic growth and energy policies 206–20
energy strategies 205–209
summary solutions: alternative policy mix scenarios 206
production sector 185–6
resource sector 185–6, 195
system dynamics modelling for energy analysis 182–3
thermal capacity development 195, 207
Rio+20 meeting 32
risk-averse attitude 209
Romania 219, 225, 226–7, 233
root mean squared percentage error (RMSPE) 190–92
safe minimum standards 295
scale efficiency models 143–4
scenarios of sustainable development 19, 27–32, 162, 361
see also under dynamic systems models in agriculture
Scramble scenario 29
sensitivity analysis 18, 378
agriculture 252–3
mining 173–5, 176
Shell petroleum company 28
simulations for sustainable growth 29, 31, 70–71, 85–9, 335–8
simultaneous equations system 64
Singerian approach see decision-support systems (DSS) for ecosystems management
Slovakia 219, 225, 226
Slovenia 219, 225, 226
social capital 41–2
social dimension of sustainable development 45, 167, 170, 368, 377
mining 167, 170, 173, 175
see also triple-bottom-line methods
social indicators 46
social reproducibility 72–81, 363
feedback loop 77–80
feedback loop for non-renewable resource availability 77
steady-state equilibrium and neoclassical golden rule 74–6
substitutes for non-renewable resources 80–81
social responsibility 24
socio-environmental systems in agriculture 268
socioeconomic factors 261, 370

Inde
sociopolitical (human and social
capital) indicators 47
solid waste management 10
sound model 18
South Africa 232–3
Spain 223, 224, 226–7, 229, 233
see also dynamic system models in
agriculture: Huerta de Murcia, Spain
spider or cobweb diagrams 24
statistical methods 19, 20
steady-state equilibrium 65, 67–8, 70, 75
ecological reproducibility 83–5
social reproducibility 74–6
STELLA computer software 18, 61–2
stepwise approach 12
stochastic modelling 378
stock-flow relation equation 64
strategic objectives 44
strong measures/indicators of
sustainability 45–6, 57–8, 166, 282, 372
substitutes for non-renewable resources
70, 80–81, 86, 88, 363
Sudan, South 56
sustainability indicators 147
see also strong measures/indicators;
weak measures/indicators
sustainable development framework 8
sustainable development index (SDI) 44, 362
Sweden 223, 226, 232, 233
Switzerland 223, 226, 234
system dynamics (SD) modelling 9, 11, 14, 25, 29, 61–3, 64–5, 89, 362–4
energy analysis 182–3
energy management 186, 368–9
infrastructure 373
see also dynamic system models in
agriculture; system dynamics
(SD) modelling in dual
economy
system dynamics (SD) modelling in
dual economy (capitalist and self-
employed) 328–35
allocation of production resources 330
formal sector 333
income disbursement 331, 332
informal sector 333
infrastructure resource allocation
determination 334–5
infrastructure service level 333
production infrastructure and
service level 333, 334
saving propensity 332–3
taxation and government revenue
allocation 332, 333–4
transportation service level 333, 334
Taiwan 283, 324, 327
Thailand 11, 324
Theil's inequality statistics 186, 189–93, 254, 369
tool-opinion-example 9
tools–techniques–methods–model
applications 8, 9–13
transaction costs 103–104, 105, 109–111, 290–91
trickle-down effect 3
triple-bottom-line methods 21, 24, 33, 51, 154–5, 361
Turkey 223
Ukraine 233
ultimate means to ultimate ends
connections 40–41, 42
unbounded systems thinking (UST) 305–306, 308, 317, 318, 319
unified modelling language (UML) 308, 311–13
United Kingdom 34, 219
input–output modelling 23, 24
land and water management 223, 224, 226–7, 228, 231, 233
measurements and indicators 44
OOFWAT 229
Scotland 23, 24, 26, 51–2
Southern Water 229
Water Industry Act 229
United Nations (UN) 44, 303
Conference on Environment and
Development (UNCED) 4
Millennium Development Goals 51
United States 20, 28, 48
Cities Program of the Clinton
Climate Initiative (CCI) 5
electric utility plants see data
envelopment analysis
Environmental Protection Agency 311
genetically modified organisms 100, 102–103, 107, 112
Hawaii 62
ideologies and future research 33, 34
Integrated Catchment Management (ICM) 12
land and water management 220, 223, 231, 232–3
see also decision-support systems (DSS) for ecosystems management
urban form of air quality 10
urban green spaces 11
urban planning 11
use case diagrams 318
user-pays principle 292
utility decisions framework 8
utility planning sustainable development concepts 8

VENSIM software 18, 62, 249, 323, 370

water pollution 258–9, 265, 268, 269
water prices see modelling sustainable water prices in Europe
weak measures/indicators of sustainability 45–6, 57–8, 166, 282, 284
weighted personal consumption 50
Wellbeing Index (WI) 52–3, 54, 56, 57
see also Ecosystem Wellbeing Index; Human Wellbeing Index
well-being indicators 27, 34, 39, 44, 52–6
ecological 27, 39, 44
economic 44
well-being paradox 362
Wellbeing/Ecosystem Stress Index (WSI) 53–5, 56, 362
‘what-if’ scenarios 7, 184
World Bank 322
World Commission on Environment and Development (WCED) 3, 4, 303
World Governance Index (WGI) 50
World Model/World3 Model 61