ROUTLEDGE STUDIES IN ECOLOGICAL ECONOMICS

The Metabolic Pattern of Societies

Where economists fall short

Mario Giampietro, Kozo Mayumi and Alevgül H. Sorman

ROUTLEDGE

This is a wide-ranging and thought-provoking book. As a guiding biological metaphor the metabolic flow replaces the circulatory fixation of standard economics. Many insights ranging from an elaboration of Georgescu-Roegen's fund-flow model, to the clever explanation of dimensional incongruities such as "cubic dollars", and the strange case of the elephant as a dematerialized mouse will instruct and delight the reader.

Herman Daly, *Professor Emeritus, University of Maryland, USA*

Giampietro, Mayumi and Sorman clearly and convincingly show that the idea of metabolism of societies and economic systems can be a guiding principle for a new economics of production. The demise of Walrasian economics has left a void in economic theory and policy and this book goes a long way in filling that gap. On the behavioral side progress is being made to construct a realistic theory of economic decision making but the same cannot be said for the production side of the economy. The authors have taken a large step forward in constructing a framework to analyze production in its biophysical and social context.

John Gowdy, *Rittenhouse Professor of Humanities and Social Science and Professor of Economics, Rensselaer Polytechnic Institute, Troy, New York, USA.*

The Metabolic Pattern of Societies

It is increasingly evident that the conventional scientific approach to economic processes and related sustainability issues is seriously flawed. No economist predicted the current planetary crisis even though the world has now undergone five severe recessions primed by dramatic increases in the price of oil. This book presents the results of more than twenty years of work aimed at developing an alternative method of analysis of the economic process and related sustainability issues: it is possible to perform an integrated and comprehensive analysis of the sustainability of socio-economic systems using indicators and variables that have been so far ignored by conventional economists.

The book's innovative approach aims to provide a better framework with which we can face the predicaments of sustainability issues. It begins by presenting practical examples of the shortcomings of conventional economic analysis and examines the systemic problems faced when trying to use quantitative analysis for governance. In providing a critical appraisal of current applications of economic narratives to the issue of sustainability, the book presents several innovative concepts required to generate a post-Newtonian approach to quantitative analysis in the *MuSIASEM* approach. An empirical section illustrates the results of an analysis of structural changes in world and EU countries. Finally, the book, using the insight gained in the theoretical and empirical analysis, exposes the dubious quality of many narratives currently used in the sustainability debate.

Overall, the performance of modern economies across different hierarchical levels of organization and across different disciplinary knowledge systems is fully analysed and a more realistic measure of happiness and well-being is devised. The book should be of interest to researchers and students looking at the issue of sustainability within a variety of disciplines.

Mario Giampietro is ICREA Research Professor at the Institute of Science and Technology for the Environment (ICTA) at Universitat Autonoma Barcelona, Spain.

Kozo Mayumi is a Professor at the University of Tokushima, Japan, and is the author of *The Origin of Ecological Economics*, also published by Routledge.

Alevgül H. Sorman is a researcher working in the Research Group of Integrated Assessment at the Institute of Science and Technology for the Environment (ICTA) at Universitat Autonoma Barcelona, Spain.

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Routledge
Taylor & Francis Group
LONDON AND NEW YORK

First published 2012
by Routledge
2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

Simultaneously published in the USA and Canada
by Routledge
711 Third Avenue, New York, NY 10017

Routledge is an imprint of the Taylor & Francis Group, an informa business

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging in Publication Data
Giampietro, Mario.
The metabolic pattern of societies: where economists fall short/Mario Giampietro, Kozo Mayumi and Alevgül H. Sorman.
p. cm.
Includes bibliographical references and index.
1. Sustainable development. 2. Environmental economics. 3. Economic development–Environmental aspects. I. Mayumi, Kozo, 1954– II. Sorman, Alevgül H. III. Title.
HD75.6.G5155 2011
333.7–dc22

2011016301

ISBN: 978-0-415-58953-6 (hbk)
ISBN: 978-0-203-63592-6 (ebk)

Typeset in Times
by Wearset Ltd, Boldon, Tyne and Wear

Contents

List of figures xi
List of tables xvii
List of boxes xviii
Foreword xix
Preface xxii
Acknowledgements xxiv
Acronyms xxviii

1 The red pill 1
1.1 How real is the reality perceived and represented by economists? 1
1.2 The painful truth 3
1.3 The structure of the book and instructions for its use 13

2 The process of demographic change: the importance of multi-scale and multi-level analysis 22
2.1 Shortcomings of common per capita assessments 2
2.2 The intricate relation between demographic structure, social organization and economic performance 27
2.3 Lag-time dynamics: another look at ageing and immigration 32

3 Going beyond economic energy intensity and Environmental Kuznets Curves: combining extensive and intensive variables 37
3.1 Introduction 37
3.2 Multidimensional analysis requires semantic wisdom: energy intensity 38
3.3 Economic energy intensity across dimensions and scales 41
3.4 Environmental Kuznets Curves 55
3.5 Conclusion 60

4 The quality of quantitative analyses for governance: how to choose a relevant perception and a pertinent representation 62
4.1 Back to the basic epistemological challenge of quantitative modelling 62
4.2 An epistemological interpretation of the concept of complexity 64
4.3 The semiotic complex and semantic closure 65
4.4 The making of quantitative analysis: Rosen's Theory of Modelling Relation 75
4.5 Getting semantic closure when dealing with sustainability: the troubles on the normative side 79
4.6 Systemic epistemological problems on the descriptive side: the challenge of multi-scale analysis 90
4.7 Additional source of ignorance for the quantitative representation: the semiotic process entails handling a complex perception of time 99
4.8 Conclusions 102

5 A critical appraisal of conventional economic approaches to sustainability problems 104
5.1 The magic of cost benefit analysis 104
5.2 The Contingent Valuation Method: can we measure the "real" value of our planet? 110
5.3 Quantitative representations of becoming systems have an expiry date 114
5.4 The concept of sustainability entails a post-normal science: the systemic problems on the normative side faced by the use of economic narratives 119
5.5 Autistic economics: the fatal attractor of formalism nonsense 125
5.6 Conclusions 134

6 Five theoretical pillars of MuSIASEM for a new quantitative analysis of sustainability 136
6.1 The concept of grammar 137
6.2 Theoretical concepts associated with autopoiesis 146
6.3 The concept of the dynamic energy budget 154
6.4 Taming the concept of impredicativity: impredicative loop analysis 157
6.5 The mosaic effect 163
6.6 Conclusion 173

7 Building blocks of the MuSIASEM approach 175
7.1 The basic concept of metabolism 175
7.2 Operationalizing the concept of societal metabolism: Georgescu-Roegen's flow-fund model 183
7.3 MuSIASEM to analyse the metabolic pattern of societies: constraints and benchmarks on the supply side 195
7.4 MuSIASEM to analyse the metabolic pattern of societies: constraints and benchmarks on the demand side 205
7.5 Applying Sudoku procedures to the multi-purpose grammar of MuSIASEM 210
7.6 The MuSIASEM approach: a wrap up 214

8 Looking for "beyond-GDP indicators": bioeconomic pressure 216
8.1 Bioeconomic pressure: a "beyond-GDP" indicator 217
8.2 Selection of sample, materials and methods 222
8.3 Comparing BEP and GDP per capita in relation to economic development 227
8.4 Comparing BEP and GDP per capita in relation to other indicators of development 240
8.5 Representing the metabolic pattern in a three-dimensional space: "GDP p.c –exo/endo–THA/HA_{PS}" and "BEP–exo/endo–THA/HA_{PS}" 247
8.6 Conclusions 256

9 An international comparison of the metabolic pattern of modern societies at the level of economic sectors 258
9.1 Checking the viability of the dynamic equilibrium in relation to the characteristics of internal compartments 258
9.2 Data sources, materials and methods 261
9.3 A comparison of changes taking place in the EU14 countries (1992–2005) 264
9.4 Analysing the integrated set of changes across compartments in a historic view 277
9.5 The problem with energy accounting when acknowledging the existence of two distinct relevant energy forms: primary energy sources and energy carriers 282
9.6 Conclusions 286

10 Other applications of MuSIASEM 288
10.1 The analysis of urban metabolism: a grammar useful to analyse the metabolic pattern of households 288

10.2 Two case studies of analysis of urban household metabolism in Barcelona 294
10.3 A multi-scale analysis of urban waste metabolism 298
10.4 The metabolic pattern of water 303
10.5 The metabolic pattern across multiple scales: from the local to the global picture 307

11 Poor narratives and granfalloons hampering the sustainability debate: can we escape Soddy's prophecy? 316
11.1 The demographic dimension 317
11.2 The implications of peak-oil are grossly underestimated 321
11.3 The world crusade on climate change 329
11.4 The dangerous formation of granfalloons 334
11.5 Can we escape Soddy's prophecy? 340

12 What went wrong and where do we go from here? 349
12.1 How dangerous is the fairytale of perpetual growth? 349
12.2 Confusing a transitional period with a steady-state situation 352
12.3 Reason for optimism: the Robinson Crusoe effect 355
12.4 On the concept of sustainability 356
12.5 How does the MuSIASEM approach fit in? 358
12.6 What should we change in sustainability science? 360
12.7 Rediscovering Buddhist wisdom 363

Appendix: illustration of the MuSIASEM approach 365
Glossary 382
Notes 390
References 391
Index 406

Figures

1.1	Trends of world population and energy use	5
1.2	The narrative of steady-state of perpetual economic growth	6
1.3	What future scenarios can we expect? What type of de-growth?	7
2.1	The metabolism of a human population across levels	23
2.2	Relation between demographic structure and labour supply at the level of society	26
2.3	Different demographic structures of societies at different levels of economic development	28
2.4	Demographic structures of different OECD countries	29
2.5	Standard dendrogram of the allocation of hours of human activity over different compartments of a developed economy	30
2.6	Forced relation between the GDP of the whole and the rate of production of GDP per hour in the paid work sector – Spain, 1999	31
2.7	Changes in demographic structure in China, 1970–2000	32
2.8	The demographic structure of Romanian emigrants	34
2.9	Immigrant contributions of working hours to the economy of Germany	35
3.1	Changes in energy intensity and GDP per capita and changes in total energy consumption and population size for the USA, 1950–2005	39
3.2	Are elephants dematerialized versions of mice?	42
3.3	Decomposing the EEI for El Salvador and Finland	43
3.4	Comparing the EEI of Finland and El Salvador (1998–2004) on a plane	44
3.5	Trend in changes in GDP/h and energy/h for a sample of EU countries, 1992–2004	45
3.6	Flow rates of energy and added value within the UK, Germany, Spain and Ireland (1992–2005) observed at two different hierarchical levels	48
3.7	Paces of flows of energy and added value within the economy of Germany seen at three different hierarchical levels	50
3.8	An overview of the organization of data used in Figure 3.7 across the three hierarchical levels considered	51

3.9 The structure of relations over different characteristics defined across levels determining the overall economic energy intensity of an economy 53
3.10 Set of formal relations among variables defined across different dimensions and levels 54
3.11 Opening the black-box: what is behind the I = PAT relation? 57
3.12 Comparison of the metabolic patterns of two hypothetical societies 59
4.1 The semiotic complex checking the usefulness of models 70
4.2 Rosen's Theory of Modelling Relation framed within the semiotic process 75
4.3 Semiotic closure: the ideal process versus a power locked-in process 88
4.4 Multiple identities of the same geographic object over multiple scales 95
4.5 Multiple explanations for the death of an individual 96
4.6 Multi-scale accounting of tennis scores 98
5.1 The diagram of post-normal science proposed by Funtowicz and Ravetz (1991) 123
5.2 The invention of square US dollars and cubic US dollars 128
5.3 Use of square US dollars and cubic US dollars in exponential and logarithmic functions 129
6.1 Structure of the grammar used to write a rejection letter 138
6.2 Taxonomy describing the profile of allocation of THA to the required functions of society 143
6.3 The linear view of biophysical transformations in the economy 149
6.4 An overview of the analysis of the metabolic pattern of ecosystems developed by H.T. Odum 150
6.5 A first overview of the autopoietic process associated with the metabolic pattern of society 153
6.6 The dynamic energy budget associated with the metabolic pattern 156
6.7 Impredicative loop analysis (ILA) of the viability domain of mail metabolism 161
6.8 Mosaic effect over the metabolic rate of the human body and its organs 164
6.9 Mosaic effect over the metabolic pattern of energy at levels *n* and *n – 1* 166
6.10 Examples of dendrograms describing the metabolic pattern across levels 168
6.11 The flow-fund representation of MuSIASEM across three contiguous levels 170
6.12 Bottlenecks and benchmarks defined within the mosaic representation 172
7.1 The material and energy flow accounting scheme 193

7.2 Forced relation between the strength of the hypercycle and the metabolic characteristics of the whole society 197
7.3 Factors determining the difference in the metabolic pattern of the various fund elements (mosaic effect) 197
7.4 The profile of power levels across different compartments and their relative size determining/determined by the net supply of energy carriers based on Odum-graphic grammar 200
7.5 Impredicative loop analysis over requirement and supply of food in relation to the allocation of the two fund elements 202
7.6 An empirical validation of the hypothesis that gradients in demographic pressure and bioeconomic pressure do affect the value of the net supply of food per hectare and per hour in the agricultural sector 203
7.7 A simple grammar establishing a relation between the demographic structure and profile of human activities for a hypothetical society of 100 people 207
7.8 The grammar presented in Figure 7.7 applied to the analysis of Catalonia 207
7.9 The critical function of the household sector within the metabolic pattern 208
7.10 The dynamic budget of hours of paid work between the HH and PW sectors 209
7.11 The metaphor of the Sudoku game 212
8.1 Relation between BEP and energy consumption, and between BEP and GDP 227
8.2 Percentage of labour and GDP in agriculture versus GDP per capita 232
8.3 Ranking of countries according to BEP and GDP per capita and classification according to development category 235
8.4 BEP and GDP per capita across the 84 countries included in the sample, 1980 236
8.5 BEP and GDP per capita across the 84 countries included in the sample, 2007 238
8.6 Infant mortality rate (per 1,000 births) in relation to BEP and GDP per capita 240
8.7 Life expectancy at birth in relation to changes in BEP and GDP per capita 241
8.8 ELP versus BEP and GDP per capita 242
8.9 Percentage of GDP from agriculture versus BEP and GDP per capita 243
8.10 Percentage of GDP from industry versus BEP and GDP per capita 244
8.11 Percentage of GDP from services and government versus BEP and GDP per capita 244
8.12 Percentage of the workforce in services and government versus BEP and GDP per capita 245

8.13 Human development index versus BEP and GDP per capita 246
8.14 Medical doctors per 1,000 people versus BEP and GDP per capita 247
8.15 Health expenditure as percentage of GDP versus BEP and GDP per capita 248
8.16 Internet users as a percentage of the population versus BEP and GDP per capita 249
8.17 Changes in time of the characteristics of the metabolic pattern of our sample of countries (1980 and 2007) 250
8.18 The sample in the three-dimensional space: GDP per capita, exo/endo ratio and THA/HA_{PS} 251
8.19 The sample in the three-dimensional space: BEP, exo/endo ratio and THA/HA_{PS} 251
8.20 The relations between BEP and THA/HA_{PS}, exo/endo and BEP, and exo/endo and THA/HA_{PS} within the trajectory of economic growth 1980–2007 252
9.1a Metabolic profiles of selected EU countries, 1992–2005 266
9.1b Metabolic profiles of selected EU countries, 1992–2005 267
9.2 Sectoral division of energy consumption per hour versus economic labour productivity of the metabolic representations of the EU14 countries, 1992–2005 268
9.3 Metabolic patterns of Germany, the United Kingdom, Spain and Ireland across scales, 1992–2005 268
9.4 Distribution of the EMR versus the ELP of the productive sectors of the EU14 countries, 1992–2005 270
9.5 The distribution of the EMR versus the ELP of the service sectors of the EU14 countries, 1992–2005 271
9.6 The changes of the EMR for the HH sector of the EU14 countries, 1992–2005 272
9.7 The distribution of the EMR versus the ELP of the agricultural sector of the EU14 countries, 1992–2005 273
9.8 Using the mosaic effect to establish a relation between the changes in the metabolic pattern observed at different levels 275
9.9 Integrated analysis of Spain, historic series 1978–1998 277
9.10 Integrated analysis of Ecuador, historic series 1970–1998 279
9.11 A comparison of the changes taking place in the metabolic pattern of Ecuador and Spain, 1978–1998 280
9.12 A comparison of the changes taking place in the metabolic pattern of PR China, 1990–1999 282
9.13 Energetic metabolic performance versus ELP for the productive sectors 284
9.14 Energetic metabolic performance versus ELP for the service and government sectors 286
10.1 A grammar to map the exosomatic energy throughput and the requirement and supply of hours of work for a template of household type 291

10.2 An example of a grammar used for scaling the characteristics of individual household types to the characteristics of the whole household sector of a specific socio-economic system 292
10.3 Requirement of paid work hours from the service and government sector for individual age and gender categories and household typologies 295
10.4 Spatial representation of the allocation of human time for the metropolitan area of Barcelona 296
10.5 Mapping of density of waste disposal on the regional and provincial level for Italy and on the municipal level for the region of Campania 302
10.6 The dendogram split of HAW illustrated for Spain, Catalonia and Andalusia 304
10.7 Water metabolic rate versus gross value added for Catalonia across scales 2000–2008 and sectoral representation of water throughput versus gross value added for Catalonia and Andalusia, 1999–2007 306
10.8 Analysing metabolic patterns through the microscopic and naked eye view 310
10.9 The MuSIASEM application to rural systems to characterize different flows 311
10.10 Societal metabolism illustrated as before and after the industrial revolution 312
10.11 Two different metabolic patterns under the effects of trade and externalization and internalization of activities in the primary and secondary sectors 313
10.12 Cyclical illustration of metabolic patterns of societies at world level following the saying "what goes around comes around" 314
11.1 Conceptual difference between peak-oil and stock depletion using the metaphor of "peak-grain" 322
11.2 So far the pace of consumption of fossil energy has always been growing 324
11.3 After reaching a situation of peak-oil an increase in human population entails reducing oil consumption per capita 325
11.4 After reaching a situation of peak-oil an increase in oil consumption of some countries entails a reduction in oil consumption of others 326
11.5 Representation of metabolic patterns at world level and for a set of selected clusters 331
11.6 Comparison of the metabolic pattern of China and that of the aggregate of OECD countries for 1999 332
12.1 The Olduvai Theory estimating the duration of the rise and fall of industrial civilization 350
12.2 Changing economic narratives along the path of the Hubbert curve 352

A.1 The impredicative loop: human activity and consumption of food energy 366
A.2 Impredicative loop analysis: the characteristics of the whole are determined/determine the characteristics of the parts (scenario A) 370
A.3 Impredicative loop analysis: the characteristics of the whole are determined/determine the characteristics of the parts (scenario B) 373
A.4 The lexicon of the MuSIASEM grammar used for the example 379
A.5 Characterization of the two scenarios across levels 380

Tables

2.1	Allocation of human activity to paid work and household sectors and GDP for Italy and China, 1999	27
3.1	Indicators relevant for the I = PAT relation at the national level for Spain, Germany and the UK, 2005	56
3.2	List of variables for the two different societies, A and B	59
8.1	BEP, THA/HA_{PS} and exo/endo for the sample of 84 countries, 1980 and 2007	228–231
8.2	Benchmark values referring to metabolic pattern of countries	233
8.3	Definition of benchmarks for both BEP and GDP per capita for the categorization of the sample of 84 countries	237
10.1	Benchmark values for the flows associated with different crops in the agricultural sector of Catalonia	308

Boxes

5.1	Monetary valuation of the "real value" of Mother Teresa	129–131
5.2	Formalism nonsense in the Stern Review Report on the Economics of Climate	132–133
6.1	College rejection letters generated by a random sentences generator	137

Foreword

It is too rare these days to find a book on sustainability and markets that is worth the effort to open, let alone read. So convoluted and incoherent is the standard story that despair is the only possible feeling of what happens there. The conceits of science obscure that which must be made clear. The pretensions of the scientist are breathtaking. Contemporary scholarship is parasitic on original thought. And then along comes a really courageous work. It is courageous because it forces us to reckon with the world out there rather than assuming it away. Hume warned us of this problem. Most scholars do not bother to check – their models become the world they strive to understand. We have here a very special gift – it is special because it is good to think with. The conceits of modernist science deserve to be hung out to dry, and here the authors make a marvelous start on that long-overdue vanquishing. Giampietro, Mayumi, and Sorman offer us a wonderful and instructive holiday from drivel. They show us that the world insists on being taken seriously. Wittgenstein's first maxim is "The world is everything that is the case." Conjured models – formalist contrivances – will never feel the same again.

Daniel W. Bromley*, Anderson-Bascom Professor of Applied Economics (Emeritus) University of Wisconsin-Madison, USA – Editor of LAND ECONOMICS*

This is a profound and courageous work that provides a many-sided analysis of our current predicament. Its recommendations may not be sufficient for a solution, but it is clear that something along these lines is necessary. It does not reject economic analysis of society, but transforms and integrates it with the complex biophysical realities in which economic activity is embedded.

Drawing on alternative traditions in economic thought, including Georgescu-Roegen, Daly and North, it is equipped to analyse not only the facile optimism of the mainstream, but also the simplistic remedies of the sustainability advocates. In summary, the reading is gloomy, but still salutary. With *The Metabolic Pattern of Societies: Where economists fall short* we see that intelligence can be productively applied even to dilemmas as deep and intractable as humanity's survival.

By now it becomes quite implausible to deny that we are living in the final stages of a two-generation binge, when natural resources, the biosphere and

eventually credit, were all used up in the interests of a "growth" whereby there were ever larger crumbs falling from the tables of the metropolitan rich. It was really quite early in that period, in the "1970s", when geopolitical realities obtruded and the unquestioned supply of cheap resources (notably oil) came into question. But in one way or another the fools' paradise persisted, culminating in the catastrophic housing and credit bubbles which have only recently broken. The financial analysts of Wall Street have had their idiocies cruelly exposed, and the mainstream economists are not far behind. But where do we go from here? What sort of hangover will we endure, and what does it portend for the end of our Empire and its material goodies? As the authors demonstrate, there is no smooth and easy path to the dematerialized economy that we will need to adopt.

In retrospect we can see that quantification has been the opiate of the expert social-engineering classes. It has been the sigh of their mathematical barbarity, the heart of their heartless models, the soul of their world without souls. In the popular motto, "what you can't count, doesn't count", we have the echo of their basic principle, "for real love, pay cash". Where earlier cultures fostered the sins of pride and arrogance, here we have had the sanctification of greed, personified in the culture-hero Gordon Gekko.[1] And appropriately for such a debased criterion of quality, pure numerical mathematics has been the bearer of the sort of knowledge that is appropriate for the sick fantasies of the banksters'[2] low finance.

Our authors have undertaken the heroic task of rehabilitating and reconstructing the mathematics of social reality, so that it can provide insights and not delusions. The task will not be easy; the very form of numerical assertions carries the implication that it is conveying a simple truth. The possibility that a numerical assertion is sheer nonsense (as when including a string of meaningless digits) is totally excluded from this hegemonic language game. The construction of a mathematics of complexity, including (as the authors say) our perceptions and narratives along with our models, is one of the great intellectual challenges of our time.

Going beyond the economic and social dimensions, we have the deeper lessons that the authors offer to us about our condition. We are caught in the Tragedy of Change; because of the inertia in our perspectives on life, change occurs only when it is thrust upon us, either through disasters or transforming technologies. Up to now, a planned and harmonious change has been beyond our capabilities. When the inevitable change comes, much that has made Modernity worthwhile, in our socio-political institutions that have protected the fortunate among us from tyranny and corruption, will be at risk.

The basic imaginary of modern science, that everything important can be calculated, predicted and managed, will not survive. In its place we may have something like Borges' Lottery of Babylon,[3] where arbitrary fates are imposed by an inscrutable authority, eventually rendering reason itself futile. Or we may learn from other world-views, that see through the implanted need for ever more of ever more.

The inventors of post-normal science cannot but be humbled by the hope that the authors put in our creation. If we have succeeded in sketching the elements from which this great synthesis is derived, our work will have been fully worthwhile.

Silvio Funtowicz and Jerry Ravetz
Milan and Oxford, 7 April 2011

Preface

This book has been easy to write. After three years of work in the EU SMILE project on biophysical indicators, the empirical analyses produced by the youngest author primed a clear phenomenon of emergence in the mass of material, data, theoretical concepts, stories and notes accumulated during three decades by the senior authors. At that point, the various pieces of this book fell into their place, self-organizing into the various chapters without requiring much direction from the authors.

However, this book is not easy to read. Looking at the comments received from the colleagues to whom we circulated early drafts of the manuscript, the expressions most used were: "massive", "extremely dense", "tour de force", "covering quite a lot". This is a familiar situation though. One of the definitions of complexity (discussed in the text) is associated with the concept of impossibility of compressing the discussion of an issue without missing relevant aspects of it. A pun line of Timothy Allen says that the concept of complexity is like the concept of pregnancy: they both are "or" phenomena. You cannot be pregnant just a little bit or in relation to just an aspect of it: either you are pregnant or you are not. In the same way, when dealing with a complex predicament – how to generate quantitative analysis relevant for sustainability and governance – it is not possible to address only one aspect of the problem. Dealing with only one dimension, one scale or only one perspective at the time, will not address the whole problem. With this book we want to present a holistic discussion, covering the different aspects of this predicament, both in theoretical and practical terms. In relation to this point, we can guarantee the reader that this is not another book paying lip services to "sustainability science", "complexity and sustainability", "stakeholders involvement", which ends up by providing another list of things that should be done to generate better scientific analysis in the field of sustainability.

In this book we did things in a different way. As a result, we provide an innovative method capable of generating quantitative analysis relevant for sustainability discussions together with several applications. Our work is based on what we call a post-Newtonian approach to quantitative analysis. In the book, we justify why such an innovative method is needed, then we provide the theory behind the quantitative approach and we illustrate our empirical results, which in

our opinion validate it, and finally we illustrate how the debate on sustainability could be dramatically improved if only some of the sloppy narratives proposed right now by economists could be eliminated.

Coming to the post-Newtonian peculiarity of our approach, for centuries, quantitative analysis has been based on three hidden assumptions: (1) that the observer is outside what is observed; (2) that it is possible to obtain an uncontested definition of what the observed system is and what the observed system does; (3) that it is possible to make reliable observations and models, which can tame uncertainty to acceptable levels. These assumptions are essential in order to generate crisp numbers, which can indicate to policy makers the best course of action.

In the quantitative approach presented here we abandon these assumptions. As a consequence of this fact, we propose also to abandon the conventional reliance on mathematical models. Instead we propose to move to the use of "grammars". Grammars are defined in terms of a set of expected relations between: (1) semantic categories (issue definition); (2) semantic and formal categories (problem structuring); (3) formal categories (models/production rules); (4) formal categories and external referents (sources of data). The concept of grammars entails a Copernican revolution in the use of quantitative analysis for sustainability. The conventional way assumes that it is possible to get reliable and uncontested perceptions and representations of sustainability issues. After accepting this assumption, models are used to crunch numbers and find optimal solutions. Our proposed alternative works the opposite way: crunching numbers is a required step in order to individuate effective and satisfying perceptions and representations of sustainability issue. That is, within this alternative approach numbers are used to check the quality of the chosen narratives (semantic and formal categories), story-telling and goals used in a given deliberation.

In relation to the timing of this book, we want to mention the words that Nicholas Georgescu-Roegen (1906–1994) once said to Kozo Mayumi: "Do not bow to others except to yourself." With these seemingly arrogant words he wanted to indicate that we must always challenge first of all our own intellectual ability by crossing intellectual swords with another mind within ourselves. For a scholar it is essential to convince first of all himself/herself about the validity of his/her scientific results, rather than trying to convince others. When this process is finally successful, then it becomes relatively easy to convince others. Ever since the ideas of the MuSIASEM scheme vaguely appeared in the minds of Giampietro and Mayumi, around 1995, they have been engaged in trying to convince first of all themselves about its validity. Now they feel the time has arrived to try to convince others of the power and flexibility of the MuSIASEM scheme for dealing with sustainability issues.

Acknowledgements

We are very grateful to Sandra Bukkens who has been soldiering for months in the text "emerged" in the first version of this manuscript. She eliminated whole chapters, shortened the original text by at least 40 per cent, rearranged and edited the raw material, asked for better explanations and more understandable figures and tables. We are very pleased with the result, even though we must confess that because of many last-minute changes made in the text some of her painstaking editing and re-editing was eventually lost.

Our deep gratitude also goes to Professor Minoru Sasaki of Ibaraki University in Japan who has created a program of four-angle graphs at three levels by using the program R. This four-angle representation is a key idea of MuSIASEM that can deal with the impredicativity analysis for metabolic pattern of society. Many of the other visuals have been generated via online graphic tools. For Chapter 8 graphs have been generated thanks to Frank van Cappelle (2010) StatPlanet: Interactive Data Visualization and Mapping Software (www.sacmeq.org/statplanet), for Chapters 3 and 9, Google Documents, Gadgets feature has been used.

Mario Giampietro would like to gratefully acknowledge the financial support provided by: (1) ICREA – Institució Catalana de Recerca i Estudis Avançats (Catalan Institute of Research and Advanced Studies); (2) AGAUR – Agència de Gestió d'Ajuts Universitaris i de Recerca to his Emergent Research Group on "Integrated Assessment: sociology, technology and the environment" SGR2009-594; (3) EU seventh framework programme funded project "Synergies in Multi-Scale Interlinkages of Eco-Social Systems" (SMILE, Contract 217213-FP7-2007-SSH-1); (4) Norway RCN – Reflexive Systems Biology – 187969/S10 (in relation to the content of Chapter 4). Additional thanks are due for their help to Louis Lemkow, Violetta Cabello, Giacomo D'Alisa, François Diaz Maurin, Katharine Farrell, Agustin Lobo, Cristina Madrid, Giuseppe Munda, Jesus Ramos-Martin, all at the Universitat Autònoma de Barcelona, and to Timothy Allen, Maurizio Di Felice, Vaclav Smil, Joseph Tainter and Emilio Vanni.

Kozo Mayumi gratefully acknowledges financial support of Grant-In-Aid for Scientific Research (B) (20330050) provided by the Ministry of Education, Culture, Sports, Science and Technology in Japan that indirectly contributed to creating the contents of the present book. Mayumi also appreciates the financial support provided by ICTA of Autonomous University of Barcelona

through Joint European Master in Environmental Studies between 12 October and 20 December 2010 as an ERASMUS MUNDUS scholar to finish writing this book. Additional thanks are due to the following people for their spiritual and moral support as well as encouragement for the research contained in this book: Negishi Takashi, Toshiharu Hasegawa, Ryunosuke Hamada, Takeshi Murota, Hiromi Hayashi, Toru Ishihara, Yasuo Oyama, Hiroki Tanikawa, Shunsuke Managi, Herman Daly, Joan Martinez-Alier, John Gowdy, Silvio Funtowicz, Jerry Ravetz, Sandra Bukkens, Vincent Hull, Vasile Dogaru, Giuseppe Munda, Jesus Ramos-Martin, Mark Glucina, John Polimeni, Tommaso Luzzati, Sylvie Ferrari, Heinz Schandl, Giancarlo Fiorito, Katharine Farrell, Tori Mayumi, Katsuko Mayumi, Sumiyo Tashiro, Shigemi Igawa, Giichi Hirosawa, Emiko Hirosawa, Kenichirou Ohtsu, Kimiko Ohtsu, Akira Yamaguchi, Hideto Takao, Yoshie Okada, Kinzou Okada, Asami Okada and, last but not least, Yuki Okada.

Alevgül H. Sorman would like to acknowledge the FP7-SMILE Project "Synergies in Multi-Scale Interlinkages of Eco-Social Systems" that has been funding her for the three-and-a-half years of her PhD period. She would also like to send her deepest gratitude to her family who has been supporting her endlessly; being physically so far away, yet so close to the heart; Bab, Annem, Arda, Aynur, Ayda, Dayı, Bilgen, İleri Ailesi, Şensoy Ailesi, Ülkütaşır Ailesi – *her sey için çok teşekkürler*. Sorman also thanks Mario Giampietro, not only as her director and supervisor but also as her mentor whose guidance and support has enabled her to come so far. Thanks to Jesus Ramos-Martin and Kozo Mayumi for their dedicated assistance and Sandra Bukkens for her support as one of the foundational blocks to all this work. Sorman would like to acknowledge the fruitful discussions held with Aldo Femia, Sergio Ulgiati and Giusi Vetrella improving the quality control of the analysis. Also, many thanks to all friends who have been a part of Sorman's professional and personal life during this period: Ana, Amalia, Arnim and Maria, Cristina, Christian, Davidji, Dimitris and Rania, Ethem, François, Giacomo and Stefi, Giorgos, Gonzalo, Ivana, Kristina, Marti, Max, Pablo, Pere, Silvio, Talía and Tarik and many others all over the world. Lastly, Sorman would like to thank Jaime Paneque-Gálvez for his eternal patience, encouragement and love in making all of this possible.

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4 Elsevier for:
Figures 5.2, 9.12 and 11.6. From the *Journal Ecological Economics.*
5 Lawrence Livermore National Laboratory for:
Figure 6.3.
6 Gerhard K. Heilig (www.china-europe-usa.com) for:
Figure 2.7.
7 Jean Laherrere (http://aspofrance.org/) for:
Figure 11.2.

Acronyms

ABM	average body mass
AG	agricultural sector
ATP	adenosine triphosphate
BEP	bioeconomic pressure
BM	building and manufacturing sectors
CAP	Common Agricultural Policies
CBA	cost benefit analysis
COL	colonized land
CVM	contingent valuation method
DHA	density of human activity
DWD	density of waste disposal
DWP	density of waste production
EC	energy carriers
EEI	economic energy intensity
EKC	Environmental Kuznets Curve
EL	environmental loading
ELP	economic labour productivity ($/hr)
EM	energy and mining sectors
EMF	endosomatic metabolic flow
EMR	energy metabolic rate
EMR	exosomatic metabolic rate (MJ/hr)
endo	endosomatic
ES	energy sector
ET_{AG}	energy throughout in the agricultural sector
ET_{HH}	energy throughout in the household sector
ET_{PS}	energy throughout in the productive sectors
ET_{PW}	energy throughout in the paid work sector
ET_{SG}	energy throughout in the service and government sector
EU14	the set of countries included in EU15 minus Luxembourg
EU15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom.
exo	exosomatic

FAO	Food and Agriculture Organization
GDP	gross domestic product
GHG	greenhouse gas
GIS	Geographic Information System
GMO	genetically modified organism
GVA	gross value added
HA_{AG}	human activity in the agricultural sector
HA_{HH}	human activity in the household sector
HA_{PS}	human activity in the productive sectors
HA_{PW}	human activity in the paid work sector
HA_{SG}	human activity in the service and government sector
HAW	human appropriated water
HH	household sector
IEA	International Energy Agency
ILA	impredicative loop analysis
IPCC	Intergovernmental Panel on Climate Change
ISIC	International Standard of Industrial Classification
LE	leisure and education
LSC	leisure, culture and study
MEFA	Material and Energy Flow Accounting
MF	metabolic flow
MMD	material metabolism density
MuSIASEM	Multi-Scale Integrated Analysis of Societal and Ecological Metabolism
NGOs	non-governmental organizations
NSEC	net supply of energy carriers
OECD	Organization for Economic Co-operation and Development
p.c.	per capita
PES	primary energy sources
PO	physiological overhead
PPP	purchasing power parity
PS	primary and secondary sector
PS	productive sectors (includes building and manufacturing (BM) and energy and mining (EM))
PS1	primary sectors
PS2	secondary sectors
PW	paid work sector
R&D	research and development
SEH	strength of the exosomatic hypercycle
SG	service and government sector
SMILE	Synergies in Multi-Scale Interlinkages of Eco-social Systems
TET	total energy throughput
THA	total human activity
TOE	tons of oil equivalent
TPES	total primary energy supply

UW	unpaid work
WD	waste disposed
WDMR	waste disposal metabolic rate
WP	waste produced
WPMR	waste production metabolic rate
WR	waste recovered

Units

Gh	Giga hours
GJ	Giga joules (*10^9)
MJ	Mega joules (*10^6)
PJ	Peta joules (*10^{15})
TJ	Tera joules (*10^{12})

1 The red pill

> You take the blue pill, the story ends, you wake up in your bed and believe whatever you want to believe. You take the red pill, you stay in wonderland, and I show you how deep the rabbit hole goes.
>
> (*The Matrix*, 1999)

1.1 How real is the reality perceived and represented by economists?

At the beginning of the famous 1999 film *The Matrix*, the protagonist is asked whether he is willing to take the "red pill", capable of showing him the painful truth of reality, or the "blue pill", allowing him to remain within the blissful simulation of reality that the establishment wants him to see. Since then, the "red pill" concept symbolizes the possibility of getting a fresh view of something previously perceived in a different way from within a well consolidated framework. In colloquial terms, taking the red pill means accepting the need of thinking outside the box and to challenge the existing perception of the external world. This is what we offer to the reader with this book.

The problem of whether or not it is at all possible to obtain a correct and exhaustive perception of the reality should be one of the central themes in economic debate, especially if one wants to use economic analysis for normative purposes. Certainly, we do not want to get into it here. Rather we focus on the distinction proposed by, among others, Simon (1962), between "the real world" and "the decision maker's perception of the real world". Instead of reviewing the abundant literature in philosophy and philosophy of science on this topic (for a review, see, for example, Sellars, 1991; Russell, 2008), we highlight a few quotes of famous economists, useful to frame the issue: "the world we have constructed and are trying to understand is a construction of human mind. It has not independent existence outside the human mind" (North, 2005, p. 83). Note that this quote resonates with a statement of Tagore in a famous discussion with Einstein about the reality in scientific analysis: "This world is a human world – the scientific view of it is also that of the scientific man. Therefore the world apart from us does not exist. It is a relative world, depending for its reality upon

our consciousness" (Home and Robinson, 1995, p. 174). On the same line we find Georgescu-Roegen saying that: "for us nature consists of just what we can perceive. Beyond, there are only hypothesized abstractions" (Georgescu-Roegen, 1992, p. 129).

The message of these quotes is that the validation of models and beliefs can only be obtained in relation to their usefulness for guiding practical action. When dealing with a complex issue such as the sustainability of socio-economic systems, the power and strength of quantitative analysis entails a potential weakness: numbers are generated by our simplification of a complex reality that can only be represented in relation to pre-existing frameworks (Giampietro *et al.*, 2006b).

"Analytical work begins with material provided by our vision of things, and this vision is ideological almost by definition" (Schumpeter, 1954, p. 42). The consequences of Schumpeter's point are beautifully explained by Box (1979), under the heading: "all models are wrong, but some are useful". When discussing the usefulness of quantitative models Box says:

> For such a model there is no need to ask the question "is the model true?". If "truth" is to be the "whole truth" the answer must be "No". The only question of interest is "Is the model illuminating and useful?"
>
> (pp. 202–203)

To makes things more challenging, we also have to acknowledge the unavoidable existence of large doses of uncertainty – where uncertainty should not be confused with risk (Knight, 1964), as discussed in Chapter 5 – in our analysis of sustainability issues (Mayumi and Giampietro, 2006). This has important consequences for the validity of the standard neo-classical economic theory: "In a world of uncertainty, no one knows the correct answer to the problems we confront and no one, therefore can, in effect, maximize profit" (North, 1990 p. 81).

Leaving aside the discussion of whether or not economic theory faithfully represents reality, we can safely say that there are plenty of signs that the standard application of economic narratives results in models that are far from satisfactory when applied to the issue of sustainability. In this book, we first of all put in evidence relevant information about the characteristics of socio-economic systems that economic narratives have systematically missed. Furthermore, we want to convince the reader that by adopting an alternative and innovative theoretical approach, based on the implementation of the concept of societal metabolism, it is possible to create a new generation of quantitative models useful for studying both external and internal constraints to socio-economic development. These models can be used to explore the feasibility and the desirability of scenarios of alternative patterns of production and consumption of goods and services, for they allow us to specify the set of expected functions and the relative set of organized structures which are required to guarantee the expected standard of living of modern society.

1.2 The painful truth

1.2.1 External constraints limiting economic growth do exist

The recent hype of *de-growth* – translation of "décroissance", a term originally introduced by Georgescu-Roegen and recently put forward by Serge Latouche (2007) – is no more than the resurfacing of an old debate about the sustainability of modern progress taking place as early as the 1970s. The debate was fought between the cornucopians, whose leading voices were Robert Solow and Julian Simon, and the prophets of doom, among whom Nicholas Georgescu-Roegen, Paul Ehlrich and Howard T. Odum. The cornucopians fully endorsed the ideology of neoclassical economics, maintaining that technology, human ingenuity and the market would always be able to overcome any biophysical constraint to a continuous economic growth. For the cornucopians perpetual growth was not only possible, it was the very reality in which they lived (i.e. *The Matrix*). The prophets of doom, on the other hand, framed the issue of sustainability on the basis of biophysical and ecological analyses, claiming that natural resources and the fragility of ecological processes would sooner or later impose limits to perpetual economic growth (i.e. the painful truth), and hence forcing a re-discussion of the very idea of perpetual growth itself.

The result of the confrontation between the cornucopians and the prophets of doom is well known. The time was simply not ripe for the prophets of doom. Neoclassical economists successfully imposed the simplified perception and representation of socio-economic development that had worked so well in the past: the richer an economy, the better off its citizens. Why worry about the future; new technologies and inventions would take care of generations to come. In this simplification, the paramount goal is to maintain economic momentum, i.e. economic growth, by adopting policies maximizing the gross domestic product (GDP). Because of the apparent uncontested success of this policy, no quality control has ever been applied to the validity of this narrative, not even when considering the long-term view. No one but some powerless losers in this economic battle – e.g. those that did not get any richer from the implemented policies – complained.

The victory of the cornucopians has left an enduring legacy in the way modern society frames the issue of sustainability. A winning paradigm used for normative purposes naturally tends to become a political ideology. Herman Daly stigmatizes the consolidated set of ideological beliefs held by growth oriented neo-classical economists in the following paragraph:

> Growth is widely thought to be the panacea for all the major economic ills of the modern world. Poverty? Just grow the economy (that is, increase the production of goods and services and spur consumer spending) and watch wealth trickle down. Don't try to redistribute wealth from rich to poor, because that slows growth. Unemployment? Increase demand for goods and services by lowering interest rates on loans and stimulating investment,

> which leads to more jobs as well as growth. Overpopulation? Just push economic growth and rely on the resulting demographic transition to reduce birth rates, as it did in the industrial nations during the 20th century. Environmental degradation? Trust in the environmental Kuznets curve, an empirical relation purporting to show that with ongoing growth in gross domestic product (GDP), pollution at first increases but then reaches a maximum and declines.
>
> (2005, p. 78)

Besides Georgescu-Roegen and Daly, several other ecological economists have been flagging the existence of conceptual problems in the applications of economic theory to the issue of sustainability (e.g. Norgaard, 1994; Mayumi, 2001; Martinez-Alier, 2003). However, in spite of the acknowledgement of "a few systemic flaws" in basic economic assumptions – some ferocious critics, such as North and Simon, were even awarded a Nobel Prize in economics – the economic establishment did not cease to operate in the business-as-usual mode. This inertia continues even today despite the increasingly evident signs of the shortcomings of current basic economic policies: financial crisis, environmental crisis and the collapse of social fabric all over the world, just to name a few.

The following simplified example may be useful to illustrate the theoretical fallacy of the perpetual growth narrative provided by econometric analysis based on the extrapolation of past trends. Suppose we want to predict the evolution in time of the body temperature of a person experiencing a sudden onset of fever. Starting with a first reading of 36.5 °C and measuring over intervals of 30 minutes, we obtain readings of 37.5, 38.5, 39.5 and 40.5 °C. How robust would our econometric analysis of this trend be, if we predict that the observed person will reach a body temperature of 52.5 °C after the next six hours, since the fever is increasing at a pace of two degrees per hour? Clearly, if we put all our epistemological eggs in a single basket by trying to extrapolate the behaviour of a complex system in time by studying the behaviour of only one single attribute/indicator defined at a single scale, we should not be surprised that our predictions will be far off. It is only by using additional sources of knowledge, e.g. human physiology, that we can predict the existence of biophysical limits to the possible increase in body temperature. But this requires a form of knowledge referring to processes – physiological process inside cells and organs inside the human body – operating at a scale different from the scale at which we observe the effect of the fever on a given individual human being. This simple example teaches us how important it is to have a sound biophysical understanding of complex processes across different scales that is independent (non-equivalent) from the information obtained by a simple measurement scheme dealing with the time records of a single attribute of the investigated system.

The graph shown in Figure 1.1 shows the effects of this trend of economic growth in terms of the relative biophysical indicators, human population size and exosomatic energy use. As illustrated later on, by the empirical analysis presented in Chapters 8 and 9, an increase in the pace of energy use is required to

obtain economic growth. The figure shows a dramatic and abrupt increase both in population and per capita energy use in the last two centuries. This abrupt change coincides with the industrial revolution (Cottrell, 1955; H.T. Odum, 1971; Hall *et al.*, 1986; Giampietro and Mayumi, 2009) that triggered the phenomenon of economic globalization, supported by the plundering of natural resources and fossil energy. As shown by the graph, an exponential growth in population and energy use has now been going on for more than 200 years.

Consider now the expectation that a sustained economic growth of 2 or 3 per cent per year will be continuing in the future. The assumption of perpetual growth is equivalent to an ideological rotation of the axes of the graph in the perception of reality as illustrated in Figure 1.2. Something perceived as an unnatural peak when describing the effect of exponential growth in terms of total population and total energy use (Figure 1.1), is being considered by economists as the baseline (Figure 1.2) at which the world economy is supposed to go on forever! This perception of "normality" is used to characterize the performance of the economy. Indeed, the 200 years of continuous economic growth have convinced the majority of people in developed countries that it is "normal" to have a rate of economic growth of 2–3 per cent per year. And note that according to the economic theory of globalization it is also "normal" to expect an even higher rate, i.e. 7 per cent, for developing economies while catching up with their richer counter parts (for the case of China, see Aldhous, 2005; Taejoon, 2006).

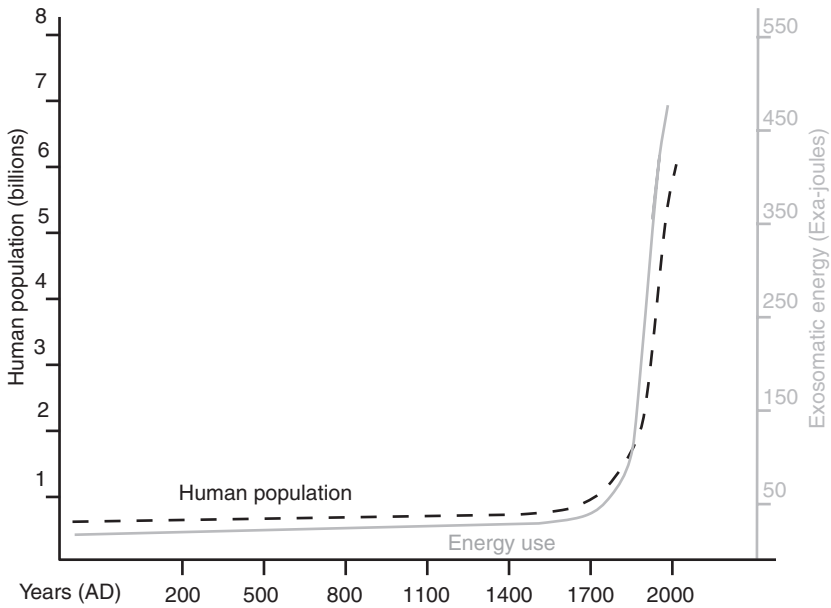

Figure 1.1 Trends of world population and energy use (source: adapted from Giampietro and Mayumi, 2009, used with permission from Earthscan).

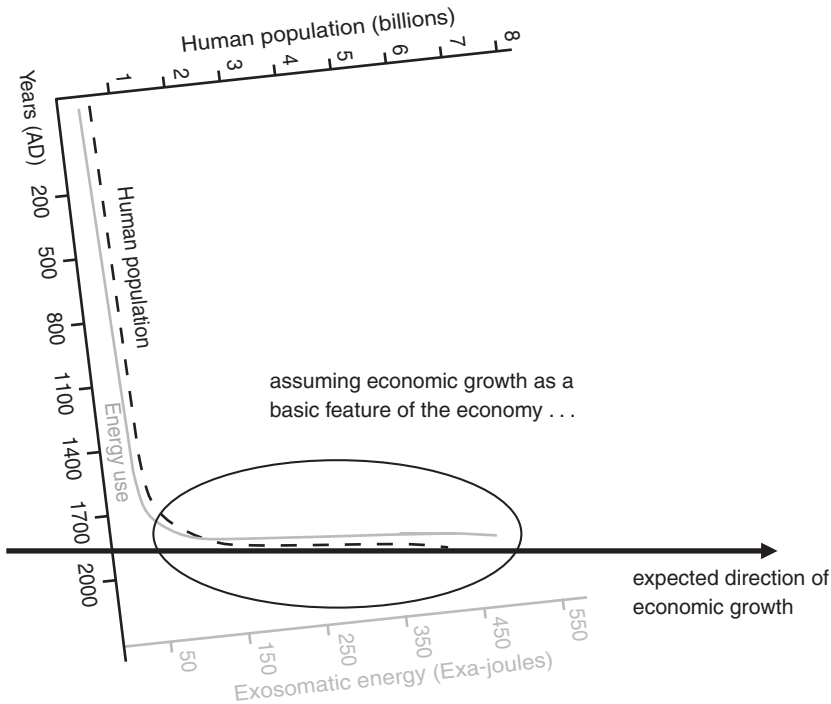

Figure 1.2 The narrative of steady-state of perpetual economic growth.

The classic tale of the kernels of rice doubled over the chessboard or of the doubling of lily pads over the fresh water pond, reminds us of the incredible power of exponential growth (Bartlett, 2004). It also reminds us that it is common knowledge that to remain constant in time, exponential growth must be associated with the stabilization of an exponentially growing size of biophysical flows requiring an exponential expansion of capability on the supply and sink side. This exponential growth cannot last for a long period of time in a finite context. The steady-state view of a sustained economic growth, tacitly assumed to be possible by most economists and politicians, appears to have totally missed the biophysical view of this process.

A famous quote of Boulding (quoted by Grant, 1988) nicely exposes this complete absence of the issue of scale in economic analysis: "Anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist." Boulding hits the nail on the head: it is impossible to keep increasing forever at an exponential rate; this is true both for the population size and the relative use of energy and other resources. Considering that the number of human beings grew in the last 35 years by three billion, which is more than the increase accumulated over the previous 35,000 years together, it is

obvious that the same pace of growth cannot be expected for the next 35 years. The curves illustrated in Figure 1.1 sooner or later will have to get out from their current path of exponential growth. Although nobody can predict what will happen in the future, in Figure 1.3 we illustrate some alternative trajectories for the trends of population and the pace of energy use per capita.

Using again his subtle irony, Daly provides a different take on the fact that sooner or later it is unavoidable to get too much of a good thing:

> Optimal allocation of a given scale of resource flow within the economy is one thing (a microeconomic problem). Optimal scale of the whole economy relative to the ecosystem is an entirely different problem (a macroeconomic problem). The micro allocation problem is analogous to allocating optimally a given amount of weight in a boat. But once the best relative location of weight has been determined, there is still the question of the absolute amount of weight the boat should carry. This absolute optimal scale of load is recognized in the maritime institution of the Plimsoll line. When the watermark hits the Plimsoll line the boat is full, it has reached its safe carrying capacity. Of course, if the weight is badly allocated, the water line will touch the Plimsoll mark sooner. But eventually as the absolute load is increased, the watermark will reach the Plimsoll line even for a boat whose load is optimally allocated. Optimally loaded boats will still sink under too much weight – even though they may sink optimally!
>
> (1991, p. 35)

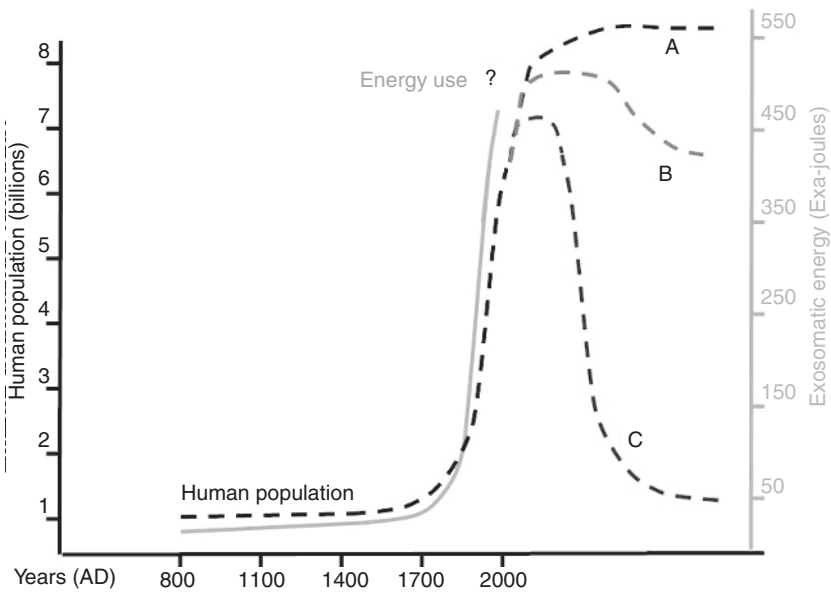

Figure 1.3 What future scenarios can we expect? What type of de-growth?

After decades of systematic neglect of the existence of external constraints in the theoretical analysis of the economic process, the issue of climate change finally forced economists to consider the possible existence of problems associated with exponential growth, at least in relation to CO_2 emission. Reluctantly agreeing on the relevance of this problem, several attempts have been made to curb the aggregate emissions of the global economy through international agreements (e.g. the Kyoto Protocol) and a variety of national ad hoc policies.

As a matter of fact, the need of getting out from a perpetual exponential growth is warranted not only by the growing concern with climate change, but also by the slowly growing awareness of other looming problems on the supply side of the economy (in relation to the requirement of resources). Peak oil and "peak-everything else", an appropriate expression recently suggested by Richard Heinberg (2005), suggests that in the near future it will be impossible to keep the cost of resources as low as it used to be. Furthermore, there is the growing awareness that existing ecological processes cannot be stressed any further by the continuous increase in scale of economic activity: collapse of fisheries, dramatic loss of biodiversity, unsustainable rate of deforestation and soil erosion are unequivocal signs of an excessive pressure of the global economy on ecological processes, as recently documented by the work of the Millennium Ecosystem Assessment (MEA, 2005).

In conclusion what we can say about the idea of perpetual growth is that those who hold this belief totally ignore the issue of scale, that is, the existence of external biophysical constraints which affect the feasibility of the expression of the three functions required for the long-term stability of the socio-economic process:

- the expression of a given pattern of production/consumption of goods and services;
- the reproduction of the required processes and related institutions;
- the development of adaptability of the socio-economic process.

1.2.2 Internal constraints on the viability of the economic process do exist, too!

If we admit that important changes must take place with regard to existing trends then it is obvious that the possibility of maintaining a large population on this planet at a decent material standard of living will depend on the ability of dramatically and quickly readjusting the current structural and functional organization of society. This brings us to another important question: does economic theory provide us with adequate and sufficient information on the internal dynamics of society in order to study the feasibility of a quick readjustment and the policies and tools to achieve it? A simple example illustrates that the answer to this question must be definitely negative.

No one would believe that at the next Soccer World Cup, the same players of the various national teams could possibly play in a competitive way during

the entire month of competition, while eating only half the food calories they eat today or producing only half the CO_2 they produce today. This scepticism is due to the fact that we know both the expected size and the expected metabolic rates of the various organs making up a human being. That is, within a human body 1.8 kg of liver consumes 9.7 W/kg of food energy, 1.4 kg of brain consumes 11.6 W/kg of food energy, 0.3 kg of heart consumes 21.3 W/kg, the 28 kg of muscles consume a certain amount of food energy and emit a certain amount of CO_2, depending on the effort. Therefore, we have enough information concerning the relation between (1) the set of organized structures (organs) making up the human body and (2) the relative functions expressed by these parts, to safely estimate the energy dissipation and the associated material flows both on the supply side and the sink side (CO_2) for a given human body carrying out a specified set of activities. Being informed, we can safely state that a 50 per cent cut in current food energy consumption is an absurd hypothesis and that we should not even think about it, at least not for our favourite national team.

Surprisingly most people do not seem to be aware that the metabolism of both societies and ecosystems is subject to the same simple rules as the human body. Otherwise the general public would not politely smile and nod along at the ambitious targets continuously proposed and agreed upon at the various world conferences on climate change (e.g. the last Earth summit in Copenhagen), that is, reductions of 50, 70 and even 80 per cent of the CO_2 emissions of industrialized countries with a time line of only a few decades. Given the worldwide public attention that these conferences draw, we may conclude that there apparently is a generalized consensus on the idea that altering the metabolic pattern of complex socio-economic systems is much easier than altering the metabolic pattern of human organisms or that it will be possible to replace soon fossil energy as our primary energy source. We must also conclude that the most reputable economic advisers of the most powerful governments keep sending their leaders to try to reach agreements that are not even close to being feasible according to simple biophysical realities, but that are defined purely on the basis of wishful thinking. In fact, as will be illustrated in this book, since the CO_2 emissions of the world economy are directly related to the consumption of fossil energy: (1) it is very unlikely that it will be possible to dramatically reduce fossil energy consumption without negatively affecting economic performance; (2) it is also very unlikely that a transition to alternative energy sources will be possible in the short to medium term.

Therefore, before setting ambitious targets, it would be wise to address first the following two basic questions:

1 Are large reductions in the actual metabolic pace of industrialized countries feasible without causing a collapse of the system? In analogy with the metabolism of human beings, will it be possible in the future to have key functional economic sectors (like the brain, heart and liver of the human body) that require 50, 75 or even 85 per cent less energy and resources?

2 If such technical adjustments are impossible, then which of the functions presently performed in our societies will have to and can be eliminated in order to reduce energy use without causing a collapse of the existing socio-economic process?

This discussion clearly indicates that besides the role played by external constraints (i.e. the possibility of securing the needed supply flow and disposing the waste flow) there are other key factors determining the feasibility of a given pattern of production and consumption. These factors do affect the possibility of implementing policies aimed at generating dramatic changes in the characteristics of the socio-economic process. These factors together determine a set of *internal* constraints. In fact, in order to be feasible a trajectory of economic growth or de-growth must not only be compatible with external constraints (sufficiency of resources and sink capacity to maintain the future pace of consumption) but also with internal constraints. That is the restructuring and the reduction of economic activity should not compromise the vital functions of the socio-economic system.

Would people accept drastic changes in their standard of living or would this induce a collapse in the social fabric, compromising the stability of the institutions? Could a series of local collapses in technological performance induce a non-reversible domino effect, making it impossible to correct the functioning of the complex set of transformations taking place in modern economies? The analysis of the feasibility of a quick readjustment to a lower level of consumption must be based on a careful analysis of internal constraints. Internal fragility may make it impossible to achieve quick structural changes, without hampering the ability of expressing the existing set of functions considered as vital for the identity of a socio-economic system. As illustrated by the fall of the former Soviet Union or the sudden disappearance of Yugoslavia, complex societies can collapse by implosion when internal constraints play a more important role than external constraints.

When studying internal constraints in relation to the feasibility of socio-economic organization we must first of all *acknowledge* the existence of an expected relation between a given set of functions and the relative set of organized structures. This integrated set of functions and structures represents a complex system operating across different scales. The integrated expression of these functions can be associated with a given pattern of consumption of resources in the socio-economic process – what we call the metabolic pattern of the society. Indeed, another serious problem affecting the perception and representation of reality typical of the standard neo-classical economic approach is its systemic neglect of a biophysical analysis of internal constraints due to excessive simplification. Economic indicators are not able to address and study the existence of these biophysical constraints.

As early as 1941, George K. Zipf, a truly creative thinker, proposed an analysis of the organizational pattern of societies seen as *bio-social organisms* (1941). In his analysis he provides many interesting new concepts, some of

which are in big fashion today in complex systems theory (Zipf, 1941, 1949). In particular, he introduces for the first time the notion of critical organization (the expression of power laws in organizational patterns), now considered an expected feature of complex dissipative systems operating across different levels of organization (Bak, 1996). Another important concept introduced by Zipf is the explicit acknowledgement of the key role that human activity plays in the economic process by boosting both the production and consumption side of the economic process: that is, in order to be able to produce more an economy must invest more human activity in consuming more! When explaining the restructuring of the US economy that took place after the great depression, Zipf says:

> Expressed differently, in 1929, the United States discovered a new "raw material": leisure time, which in a way, is just as much a "raw material" as coal, oil, steel or anything else, because for many types of human activity, leisure time, is an essential prerequisite.
>
> (1941, p. 324)

The total amount of human activity in the economic process has to be wisely invested in a balance of categories of activities determining an integrated set of functions. In relation to the need of readjusting simultaneously the whole set of compartments operating over the entire loop of supply and final consumption, Zipf remarks: "any change in kind or amount of goods or processes within a social economy will necessitate a restriation within the social economy itself" (1941, p. 324). With the term *restriation* Zipf means that in order to establish a different pattern of production and consumption within an economy, the various characteristics and relative sizes of the various compartments in charge for the transformation activities in production, the transformation activities in consumption and the transaction activities required to have effective institutions must be rearranged in a coordinated way.

In fact, according to Douglass North (Wallis and North, 1986; North, 1990) the stabilization of a socio-economic process can only be obtained by integrating the expression of two distinct typologies of functions:

1. *transformation*, which is required to guarantee both the supply and the consumption of goods (the point made by Zipf); and
2. *transaction*, which is required to guarantee the various activities of controls and of processing of information required to stabilize the institutional setting in which both the production of economic flows and the reproduction of economic funds are coordinated.

Without an effective institutional setting the transaction costs per unit of item produced and consumed will hamper the possibility of growing the transformation sectors. Therefore, when dealing with the analysis and the evolution of a socio-economic system it is impossible to consider in isolation these two different functions, which are carried out within any functioning economy by an

integrated set of different organs having different characteristics – so to speak. The various economic sectors and subsectors of the economy (including that of final consumption) must be able to operate in an integrated way thus generating an emergent property of the whole.

When considering possible scenarios of change in existing world trends (e.g. Figure 1.3) things become more complicated because we have to deal with different typologies of socio-economic processes operating across different hierarchical levels of organization. That is, if we add to the goal of reducing global emissions also the goal of a quick development for less industrialized countries, to which the majority of the 6.8 billion of present population belongs, then we face two distinct challenges that are difficult to analyse in a single representation.

By using again the metaphor of the human body we can describe those socio-economic systems in need of further economic growth/development as organisms that still need to grow their organs both in size and in intensity of activity. Then the challenge of sustainable development can be expressed as follows: will it be possible for these organisms to build an entire set of new structures needed to generate a more elaborated set of functions (expressing much more transformation and transaction activities) while consuming less energy? Can this be achieved simply by transferring more sophisticated technology to less developed countries?

To answer this last question, we had better adopt a more complex view of the economic process. As suggested by North, such a view has, first of all, to acknowledge the key role that institutions play in making possible economic growth by reducing transaction costs. In fact, the set of activities carried out in a society are not only related to the production and consumption of goods (what North calls the activities associated with the transformation function). Any socio-economic system must dedicate an important share of its activity (and resources) to the expression of another crucial function: the *transaction function* (Wallis and North, 1986; North, 1990). In other words, a functioning set of institutions are required in any socio-economic process in order to reduce the uncertainty faced by agents operating at different hierarchical levels, and therefore to reduce the transaction costs which unavoidably must be added to the transformation costs. The more complex is the economic activity, the greater will be the requirement for the expression of an effective transaction function. The industrialization and post-industrialization of modern economies are based on a constant development of more effective institutions and organizations, which requires a growing share of the total consumption of resources!

> For those economies that could realize their potential of productivity implications have resulted in standard of well being simply unimaginable by prior generations. But to realize the advantages of this technology has entailed a fundamental restructuring of economic activity and more than that of the entire society. The economic restructuring involves realizing the productive implications of world-wide specialization and division of labour.
>
> (North, 1990, p. 4)

The key role of effective institutions in making possible economic development is further explained in the following paragraph:

> when we compare the cost of transacting in a Third World country, with that in an advanced industrial economy, the costs per exchange in the former are much greater – sometime no exchange occurs because costs are so high. The institutional structure in the Third World lacks the formal structure (and enforcement) that underpins efficient markets.
>
> (North, 1990, p. 67)

In these two passages North suggests the need of addressing a new typology of qualitative change that must be associated with economic development. If Zipf suggested that within the transformation function the ability of increasing the production side must be associated with the ability of increasing the consumption side, North suggests that within the activities related to the paid work sector an increase in the productivity of the transformation function (primary and secondary sectors) has to be associated with an increase in the effectiveness of the transaction function (in the tertiary sector). Again we find the concept that economic development has to be perceived as an integrated set of qualitative and quantitative changes of different parts of the whole expressing different functions (all economic sectors including that of final consumption) within an evolving characteristic of the whole.

The study and representation (based on "beyond growth" biophysical indicators) of the existence and the nature of these internal constraints will be illustrated in detail in Chapters 8 and 9.

1.3 The structure of the book and instructions for its use

According to Timothy Allen an established scientific paradigm can be considered as a tacit agreement not to ask certain questions. This is very true for whoever tries to challenge an established paradigm within our academic universe. Innovators face an invisible wall impossible to breach. If you attack the paradigm in theoretical terms, your work will be discredited because of lack of empirical validation. If you present empirical data challenging the validity of the established paradigm, your work will be rejected because of lack of theoretical back up. If you present both an alternative theoretical framework and empirical evidence based on this alternative framework, your work will simply be ignored because it is no longer considered relevant for the discipline: you are considered a hostile outsider.

Given the lifetime experience of heterodoxy of the two senior authors (M.G. and K.M.), we realize that the only possible way out of this impasse is to present together:

- a robust theoretical part with a critical appraisal of existing applications and a clear presentation of the proposed alternative;

- a sound empirical validation with a lot of applications showing that it is possible to generate quantitative analysis in an alternative way and that the results thus obtained do validate the proposed theory;
- a convincing dialectical discussion with reference to hot topics in the field of sustainability, showing that both the theory and the empirical analysis presented are relevant for discussing sustainability issues and for generating better economic analysis.

Implementing this plan has resulted in the rather voluminous text you are holding in your hands. We can reassure the reader that this is not the umpteenth book making the point that the scientific analysis of sustainability issues should be done in a different way. This book actually presents *the very results* of years of thinking outside the box and doing quantitative analysis in a different way. Because of this fact, we admit that it is not exactly easy reading material. Academicians, economists and non-economists alike will find discussions carried out using unfamiliar narratives, theoretical terms and acronyms. Non-academicians will run into academic discussions, explaining where and how we got out of the box. We understand that these discussions may be annoying and irrelevant for them. For this reason we provide below a brief description of the contents of the book and the role of the various chapters. We hope that this may help the interested reader navigate through book.

The sceptical readers, looking first of all for the "beef" (practical results), should go through the first three chapters, introducing the issue with practical examples, then skip the theoretical parts of Chapters 4, 5, 6 and 7, take a good look at the main empirical results presented in Chapters 8, 9 and 10, and check the final discussion presented in Chapters 11 and 12. At that point, those who found the empirical results and the dialectical discussion convincing – "if the theory were robust, this is an approach worth of attention" – can go back to the central chapters to check out the theory.

The academic readers interested in checking, first of all, the theoretical robustness of this book may want to adopt the opposite approach. They can start from the theoretical discussion provided in the middle of the text dealing with two completely different issues. The first two chapters of this block present an epistemological analysis of the problems found when trying to use quantitative analysis in the process of decision making both in general terms (Chapter 4) and in relation to the use of economic narratives (Chapter 5). The second two chapters of this block present in details the theory behind the innovative approach proposed and used in this book, i.e. Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM). In particular, Chapter 6 illustrates a series of innovative theoretical concepts used for developing the approach, and Chapter 7 presents the methodological approach in details.

The dedicated readers who trust the judgement of the authors and are not in a hurry may decide to go through the text the way we organized it. In this way they will get the mix of theoretical and practical information in the order we saw fit. First, practical examples indicating the existence of serious problems with the use of conventional economic indicators (Chapters 2 and 3); then a detailed

explanation of why the conventional approach based on reductionism does not work when quantitative analysis has to be used to deal with governance (Chapter 4). This general epistemological analysis is used, in Chapter 5, to explain the poor performance of economic analysis applied to the issue of sustainability. These two chapters indicate the need of alternative approaches to quantitative indicators. In relation to this point Chapters 6 and 7 illustrate that it is possible to develop a new approach to quantitative analysis capable of generating results relevant for sustainability discussions. In particular the MuSIASEM approach can generate useful "beyond GDP indicators" of socio-economic development. The empirical analysis (Chapters 8, 9 and 10) confirms this claim and the final two chapters (Chapters 11 and 12) wrap up the discussion. Humankind is living in times of swift changes taking place at the scale of the whole planet. It is urgent to develop more effective methods of analysis in order to study the sustainability of human activities.

A more detailed description of the content of the various chapters follows.

1.3.1 First dialectical discussion (Chapters 2 and 3)

These chapters illustrate, with simple and practical examples, the shortcomings of standard quantitative analysis based on economic narratives and the relevance of our proposed alternative approach. These chapters introduce the motivation of our research as well as the basic ideas and concepts.

Chapter 2 focuses on the relevance of demographic variables, often neglected by economic narratives, from a practical perspective. Indeed, the vast majority of statistics describing national economies are based on per capita values and this presents some serious problems. As we will show, a characterization based on per capita data implies the choice of a single hierarchical level (the whole) for characterizing the socio-economic system and hence these data cannot be used to explain differences among internal structure of countries or to provide causal relations associated with internal constraints (i.e. how the characteristics of the parts affect/are affected by the characteristics of the whole).

Chapter 3 focuses on the importance of adopting a multi-scale approach to study the effects of changes in the characteristics of the internal compartments of society. Its main purpose is to show that commonly used economic narratives to study the biophysical efficiency of the economic process neglect this idea and therefore totally miss the point. In this context, we closely examine the indicator economic energy intensity and the idea of dematerialization of the economy. We show that in order to understand the factors determining the biophysical performance of economies it is necessary to open the black-box and look at the characteristics of the various parts. Then by considering both the characteristics of each part (qualitative aspects using intensive variables) and its relative size (quantitative aspects using extensive variables), one can establish a relation between the characteristics of the parts and those of the whole. The rosy hypothesis of Environmental Kuznets Curves is used as a case study to show the theoretical confusion generated by the careless use of economic narratives to deal with the issue of scale in relation to sustainability.

1.3.2 An epistemological analysis of the predicaments associated with the generation of quantitative information when dealing with the issue of sustainability and a critical appraisal of the use of economic narratives for this purpose (Chapters 4 and 5)

Chapters 4 and 5 discuss in theoretical terms why it is difficult to generate quantitative analysis useful for governance of sustainability and why economic analysis alone cannot achieve this purpose especially the way it is used today.

Chapter 4 focuses on the epistemological problems likely to be encountered when generating quantitative analysis for governance. We warn the reader that this is the densest and longest chapter of the book. Especially for people unfamiliar with the topic, it may a hard nut to crack. In this case we suggest to skip this chapter and to get back to it, after having metabolized the rest of the text. In this chapter we argue that when dealing with the process of decision making any given issue definition of sustainability problems depends on a series of pre-analytical choices referring to both normative and descriptive aspects. Therefore, the usefulness of quantitative information generated within a given issue definition depends on: (1) the relevance for social actors of the narratives used when choosing models and indicators – quality of the choices on the normative side; and (2) the pertinence of the quantitative representation – quality of the choices on the descriptive side. On the normative side, different story-tellers will define, using different criteria, what should be considered as a relevant issue definition. This means that the decision of what should be considered either a useful model or a useful set of indicators cannot be a substantive one. We draw on the Theory of Modelling Relation developed by Robert Rosen to individuate, within the various phases of the semiotic process, the specific steps in which semantic checks are required. We use the ongoing discussion over climate change to illustrate in practical terms, the problems found when using quantitative analysis for dealing with sustainability issues defined at the global scale.

The main message of Chapter 5 is that it is impossible to use standard economic narratives based on methodological individualism for dealing with the issue of sustainability because of a series of epistemological problems. First, the choice of goals and relevant attributes used in the optimizing models may not coincide with the definition of relevance used by social actors affected by the policy. Second, the choices of quantification adopted so far – e.g. using prices referring to exchange value to assess the value of special and unique entities – are inconsistent with economic theory. Third, sustainability and evolution entail a clear need of addressing the issue of scale, an issue that quantitative analysis based on economic narratives totally ignores. Last, but certainly not least, quantitative analyses relevant for the issue of sustainability are unavoidably affected by large doses of uncertainty. This implies an additional limit: when dealing with genuine ignorance, risk analysis is inept. For these reasons, those who generate quantitative analysis based on standard economic narratives according to the paradigm of substantive rationality are fatally bound to get into the attractor

of "formalism nonsense". Most mathematical models used by economists are like the Latin language used in the old times: they play a role in legitimizing decisions that have already been taken by the establishment.

1.3.3 A presentation of innovative theoretical concepts used in the multi-scale integrated analysis of societal and ecosystem metabolism (Chapters 6 and 7)

Chapters 6 and 7 present, in theoretical terms, our proposed alternative approach: a multi-scale analysis of the metabolic pattern of modern societies. These chapters introduce several theoretical concepts, developed in various scientific disciplines over the last decades, that were unavailable to the founders of economic theory. These concepts require the a priori acknowledgement of the epistemological challenges of complexity (multiple-scale, non-linearity, impredicativity, unavoidable presence of uncertainty) to generate a quantitative analysis that goes beyond the simplification of Newtonian science.

Chapter 6 illustrates the building blocks of the method proposed in this book. In particular, we propose to abandon the use of models in favour of *grammars*. In this way, quantitative analysis remains semantically open and can be based on the simultaneous use of non-equivalent descriptive domains (multi-scale). Further, the theoretical concept of autopoiesis is proposed to handle the challenges entailed by multiple causality and impredicativity. Indeed, the analysis of autopoietic systems (systems making themselves) requires moving from a linear to a circular view of bioeconomic processes and the acknowledgement of non-linearity and uncertainty. Theoretical considerations developed in the field of non-equilibrium thermodynamics are put forward to define the viability domain of a metabolic pattern, by determining the conditions of equilibrium of the dynamic metabolic budget of a socio-economic system. This type of analysis also requires taming the concept of impredicativity. To this purpose, we propose an approach called "impredicative loop analysis", which can be used within the framework of the metabolic pattern. Finally, in order to guarantee the congruence of quantitative representations associated with non-equivalent descriptive domains, across different hierarchical levels and scales, we suggest drawing upon the concept of "mosaic effect across levels".

Chapter 7 explains the application of the flow-fund model proposed by Georgescu-Roegen within our proposed MuSIASEM approach. This application combines the various concepts introduced in Chapter 6 in a multi-level grammar allowing us to analyse in quantitative terms the metabolic pattern of societies using a Sudoku procedure. The very concept of metabolism entails: (1) the existence of an integrated set of processes (anabolism and catabolism) for the stabilization of a given dissipative pattern; and therefore (2) the need of representing such a process simultaneously on multiple scales. This fact implies a series of epistemological challenges to be addressed by those willing to carry out metabolic studies. Georgescu-Roegen proposed a flow-fund model to deal with these epistemological challenges especially in relation to the representation of processes taking place across different scales. With this approach it is possible to

establish a link between an integrated set of fund elements metabolizing their specific flows – i.e. the various compartments of a society – and the resulting emergent property of the whole. By exploring the flow–fund relation we can make a crucial distinction in the pattern of exploitation of resources between: (1) stock-flow resources (fossil energy, mineral) and (2) fund-flow resources (renewable energy, environmental services). Then, it becomes possible to also define, in quantitative terms, the expected set of relations determining the viability domain of the metabolic pattern, by using the various building blocks described in Chapter 6. In particular, we can define, within a given metabolic pattern, a set of viability constraints on the characteristics (qualitative and quantitative) of the various sectors of a socio-economic system.

1.3.4 Empirical validation (Chapters 8, 9 and 10)

Chapters 8 through 10 present empirical results validating our proposed alternative approach to quantitative analysis to generate "beyond GDP indicators". The quantitative analysis of the metabolic pattern of modern societies is carried out by mixing biophysical, demographic and economic variables across scales, while dealing with the unavoidable non-linearity typical of autocatalytic processes. The goal of these chapters is to show the reader that it is possible to carry out quantitative analysis of the economic process based on economic and biophysical variables and the simultaneous consideration of multiple scales. Clearly, the information coming from this quantitative analysis does not substitute the information generated by economic analysis, but rather it complements it especially in relation to the choice of explanatory models and robust scenarios.

In Chapter 8 we provide an empirical analysis of the changes in the overall characteristics of the metabolic pattern of modern societies over a period in time (1980–2007) over a significant sample of 82 countries. The results show that the MuSIASEM grammar can be used to generate useful biophysical indicators of economic development, which are not based on monetary variables. These "beyond GDP" indicators can be related to the characteristics of the socio-economic systems as a whole (looking at emergent properties of the whole – overall indicator of development and structural pattern). These indicators can be related to the expected characteristics of compartments defined at different levels and scales (compartments and sub-compartments as shown in Chapter 9) and to the interface of societal and ecosystem metabolism (as shown in Chapter 10). Moreover, this analysis of the dynamic budget associated with the metabolic pattern makes it possible to define in non-equivalent ways: (1) its feasibility – what is biophysically possible; and (2) its desirability – what is expected as a minimum acceptable performance on the socio-economic side. When studying changes in the metabolic pattern over historic series, we can notice that all developed countries are following a common trajectory. This common trajectory is determined by the need of changing in a coordinated way the profile of investments of their internal fund and flow elements over: (1) transformation activities (in supply); (2) transformation activities (in consumption); and (3) transaction activities (referring to the whole process).

In Chapter 9 we provide an empirical analysis of changes in the metabolic pattern of EU14 sample in 15 years based on a multi-scale characterization. This analysis shows the existence of an expected "blueprint" for the metabolic pattern of EU countries (and other developed countries). That is, looking at their metabolic pattern it is possible to define an expected set of quantitative values (benchmark values) for the different compartments making up the economy of developed countries. This approach provides an explanatory framework to study the difference in performance found among countries. Moreover, the metabolic pattern establishes a scaling relation between the macro-economic characteristics of an economy and the characteristics of its lower level elements. In this way, by studying the existence of different typologies of constraints to the evolution of viable metabolic patterns, we can define in quantitative terms the quality (viability and desirability) of alternative energy sources. However, this multi-level analysis indicates a problem in the way energy statistics are compiled at the moment, which makes it difficult to carry out a useful analysis of the metabolic pattern at the level of individual economic activities.

In Chapter 10 we present a series of applications of the MuSIASEM quantitative approach to different sustainability issues. In order to focus on the interface between societal and ecosystem metabolism some applications characterize the metabolic pattern in spatial terms. Our message here is that when dealing with sustainability it is necessary to adopt a diversity of narratives, which in turn entails the generation of different types of quantitative analysis based on the adoption of different descriptive domains at different scales. The first application illustrates the need of developing "ad hoc" grammars for the analysis of urban metabolism. In fact, the study of the urban metabolic pattern requires dealing with a pattern of very concentrated biophysical flows: the economic process taking place in urban areas generates more than the 95 per cent of the GDP using less than 3 per cent of colonized land. The second application provides an analysis of the pattern of consumption of households by tailoring the quantitative representation to the specific characteristics of each urban system. The pattern of activity of the household can be described using GIS techniques defining spatial patterns of consumption. The third application deals with a multi-scale analysis of the metabolic pattern of waste in urban areas. The fourth application deals with a multi-scale analysis of the metabolic pattern of water. In this application the MuSIASEM approach is used to show the possibility of integrating the urban metabolic pattern with that of rural areas. Rural areas are made up of typologies of colonized land characterized by a very diluted density of monetary flows (hardly visible in macroeconomic analysis), but which are responsible for the vast majority of food supply and the consumption of an important percentage (more than 70 per cent) of fresh water. Finally, in the last section we provide an overview of the possibility of integrating the non-equivalent views of the metabolic pattern of societies using narratives referring to different scales (the microscope, the naked-eye, the telescope and the satellite view). In this way, it becomes possible to get a holistic view of non-equivalent description of the interaction of socio-economic systems and ecological systems.

1.3.5 Dialectic discussion of the material presented and wrap up (Chapters 11 and 12)

The last two chapters get back to a discussion of the relevance of the material presented in this book. We argue that at present the general understanding of the sustainability predicament is quite poor and that changes in existing trends are possible, but that they require accepting the obvious fact that the metabolic pattern of modern societies must be adjusted to new biophysical realities, the sooner the better, rather than sticking with the denial of the need for a radical change.

In Chapter 11 we intend to convince the reader that the vast majority of quantitative analyses used right now for discussing sustainability issues are based on narratives and story-telling of questionable usefulness. We focus on five points:

1 Contrary to what seems to be assumed by the politically correct view on development, the population bomb is not diffused by demographic transition and the problem of ageing of rich societies is not solved by immigration. A biophysical analysis of the factors determining the demographic transition shows that the existence of gradients of economic development translates into a migratory pump: hours of human activity are generated where they have a lower cost of production, and then when becoming adults, they tend to move to developed countries where they have a higher economic return.
2 The phenomenon of peak-oil is severely underestimated in current discussions over sustainability. Peak-oil is not about a looming exhaustion of fossil energy stocks, but rather it is about the end of the option of expanding at will the pace of fossil energy consumption of the world economy. That is, the world economy has moved from an "expanding pie" situation to a "zero-sum game" situation. This change is taking place at the very same moment in which we are experiencing the maximum pace of expansion of fossil energy consumption of less developed countries. In a zero-sum game, an increase in fossil energy consumption in developing countries requires a reduction of fossil energy consumption in developed countries, or vice versa. The most worrisome effect of peak-oil is related to the impossibility to pay back the huge amount of debt accumulated in the world economy. Without further economic growth it will be impossible to handle such a debt.
3 The obsessive compulsory attitude towards climate change. A well known human strategy to cope with stress is about transforming a complex phenomenon, which would imply reflexivity – the need of changing our own identity – into a simple technical problem that can be fixed with a "silver bullet" solution (e.g. finding the right price of a ton of CO_2). As a matter of fact, when looking at the implications of the metabolic pattern of modern societies, one can conclude that if humankind remains within the existing metabolic pattern: (1) it will be impossible to increase the current pace of economic activity because of peak-oil; and (2) any reduction of energy use will be painful. It is simply impossible to remain in the "business as usual" path. For this reason, rather than focusing sustainability discussions only on

technicalities related to climate change, the society should rather discuss how to generate a radical change of social institutions.

4 The cultural resistance to change (institutional lock-in) is behind the dangerous formation of "granfalloons". Granfalloons can be seen as social crusades to save the world based on wishful thinking rather than on solid analysis. The movement of "de-growth" is used as an example of granfalloon: an attempt to use economic narratives to fight the story-telling of perpetual growth. However, it is unclear what is special in this old wine sold in new bottles. The problem associated with a poor understanding of the sustainability predicament is exactly generated by the use of economic analysis. At the moment economic analysis does not fly with the issue of sustainability nor the economic policies suggested by the de-growth movement. Should we make plans for de-growth, or rather should we be worried by it?

5 The progressive elimination of any reference to biophysical realities in the globalized economy – after abolishing the golden standard world economies moved from the use of "fiat-money" to the use of "debt-money" – has implied that quantitative accounting in monetary terms is increasingly based on beliefs only. Indeed, we are now living in the era of Ponzi scheme economics.

In Chapter 12 we argue that the ideological intoxication of optimism of neoclassical economic theory has been determined by historic reasons and it has worked so far pretty well – at least for those that took advantage from the plundering of natural resources and energy stocks associated with economic development. However, this intoxication may generate very dangerous consequences for humankind if it is not addressed and corrected as soon as possible. Our main message is that between the two extreme visions of cornucopians and prophets of doom we have to find a middle way. However, this will require changing the existing one-sided story-telling over sustainability imposed by cornucopians and developing a new method of analysis capable of describing the existence of biophysical constraints. In the face of all these problems there are plenty of reasons for optimism. There is plenty of room for scaling down existing levels of fossil energy consumption and the power of human beings to adapt to new situations is almost unlimited. In order to release this incredible power, we must stop the denial and acknowledge the urgent need for change.

1.3.6 Appendix: illustration of the MuSIASEM approach

In the Appendix we illustrate with a simplified example of a hypothetical society living on a remote island, the integrative power of the MuSIASEM approach for the discussion of scenarios and the deliberation over possible policies in relation to the issue of sustainability.

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