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Actions and Networks



Editor: Gianluca Manzo
GEMASS, Centre National de la Recherche Scientifique (CNRS) and University of Paris–Sorbonne, France

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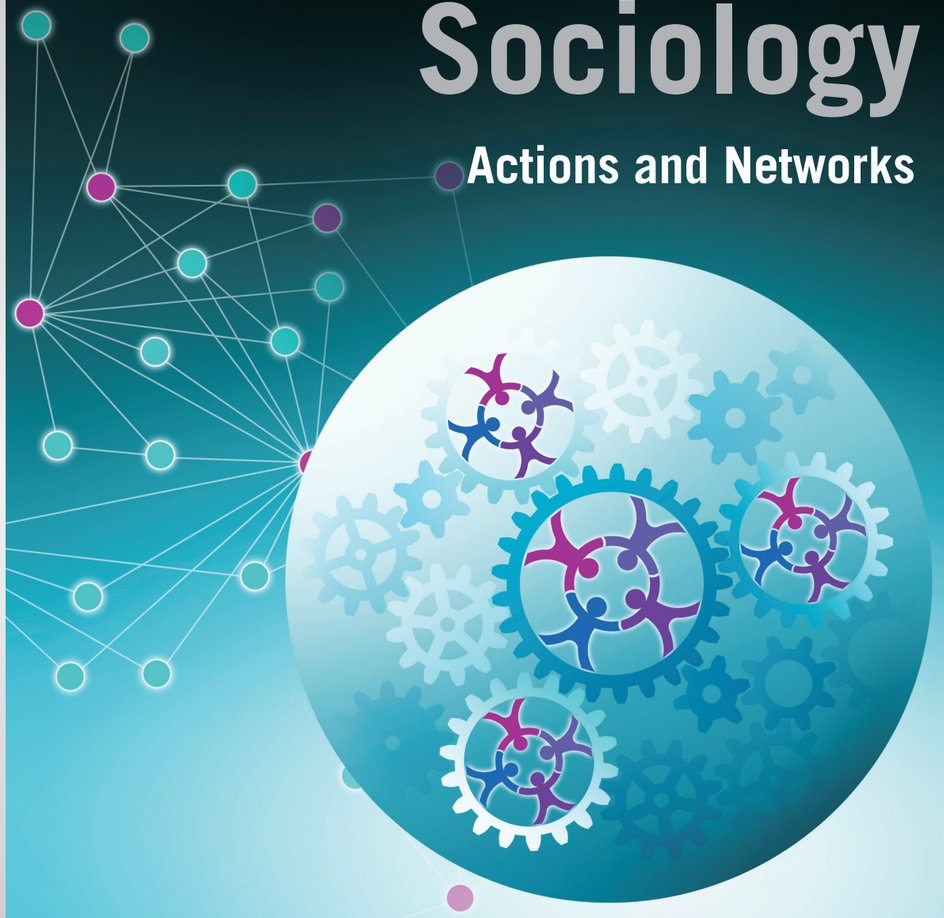
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Editor's introduction to Chapter 1

> The computer is even more revolutionary as an idea, than it is as a practical device that alters society – and we all know how much it has changed our lives. Why do I say this? Well, the computer changes epistemology, it changes the meaning of "to understand". To me, you understand something only if you can program it. (You, not someone else!) Otherwise you don't really understand it, you only think you understand it.
>
> (Gregory Chaitin 2006 [2005] *Meta Math! The Quest for Omega*, Vintage Books, p. xiii)

As the book's subtitle suggests, Hedström's *Dissecting the Social* had the fundamental goal of clarifying the theoretical and methodological principles underlying the research program of analytical sociology. Despite Hedström's admirable effort, many observers' reactions to analytical sociology over the last 10 years suggest that the intellectual project behind analytical sociology is still often misunderstood. Although the interest in analytical sociology is growing rapidly, criticisms are also recurrent. In this chapter I start with the idea that the current internal heterogeneity of analytical sociology and the complexity of its theoretical and methodological proposals help explain both its success and the criticisms that it receives. I then take these criticisms seriously and let them guide me in an attempt to remedy the most recurrent misunderstandings of analytical sociology's principles. To this end, I shall defend a specific understanding of analytical sociology as a set of principles defining a research program in the sense of Lakatos. The essay discusses each of these principles in detail, as well as their interdependence. It argues that the interdependence among the principles is the fundamental feature of analytical sociology's distinctiveness within contemporary sociology. The argument is that this interdependence arises from a specific understanding of the concept of mechanism. According to this understanding, a mechanism-based explanation amounts to a reverse engineering operation: an observation is explained only when it can be recreated. Once this is posited, it follows that some methods are more appropriate than others for designing models of mechanisms (i.e., "generative models") and studying their high-level consequences. The chapter explains the basic generic elements composing generative models

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and why the technical foundations of agent-based computational modeling put this method at the core of analytical sociology. The chapter clarifies that accomplishment of this research program depends on a clear division of labor among quantitative and qualitative scholars, formal modelers, and experimentalists. When all these elements are brought together, analytical sociology clearly stands apart as an empirically oriented, experimentally and computationally based, macro-sociology with clearly explicated and empirically grounded dynamic micro- and network-level foundations. The chapter concludes by suggesting that *Analytical Sociology: Actions and Networks* should be read as a suite of variations on a common theme, this theme being the kind of analytical sociology discussed in this chapter. The book's aim is to accumulate elements that may foster the further development of this kind of analytical sociology. *Analytical Sociology: Actions and Networks* is not intended to be about the past or the present of analytical sociology: it points to (one of) its possible future(s).

1

Data, generative models, and mechanisms: *More* on the principles of analytical sociology

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1.1 Introduction

The contemporary meaning of the term "analytical sociology" started to circulate informally through European academic space in the mid-1990s (see Manzo, 2010: 138). Still absent from the seminal collection of essays by Hedström and Swedberg (1998a) on social mechanisms, the expression "analytical sociology" officially entered the sociological vocabulary with Hedström's *Dissecting the Social* (Hedström, 2005) to denote the sociological perspective that seeks systematically to formulate and empirically test micro-founded, mechanism-based explanations of complex macro-level patterns and dynamics.

Despite the considerable efforts at theoretical clarification made by Hedström (2005), and despite the conceptual richness of the essays subsequently collected by Hedström and Bearman (2009a) and by Demeulenaere (2011a), doubts have been raised concerning the need for analytical sociology and its originality. Qualitative-oriented symbolic interactionists (see Sawyer, 2007; 2011), pragmatists (see Abbott, 2007a; Gross, 2009), cultural sociologists (Lizardo, 2012; Santoro, 2012), rational-choice theorists (Opp, 2007; 2013a), as well as philosophers of social sciences like Bunge (2007) or Little (2012a), have all criticized analytical sociology's understanding of mechanism-based thinking as based on narrow and unoriginal theoretical foundations.

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This is an interesting puzzle for (historically oriented) sociologists of knowledge. Indeed, when one considers the arguments brought against analytical sociology (see, in particular, Lizardo, 2012), it seems as if some authoritative scholars have artfully constructed an unoriginal sociological approach with an uncanny ability to mobilize a large stock of institutional and cognitive resources and to attract a considerable amount of attention, including that of scholars who feel it necessary to attack this new intellectual construct and denounce its emptiness, thereby opening the eyes of its blind followers.

At first glance, this puzzle can be resolved by positing that both the construction of analytical sociology and the critical reactions against it simply result from a struggle for academic identity in which false problems and transitory novelties arise because actors intentionally emphasize minor points while ignoring the fundamental ones. I prefer to take seriously, and believe in the intellectual honesty of, both the advocates and critics of analytical sociology. It well may be that the diversity and complexity of the cognitive content of analytical sociology explain both the attention received by the approach and the objections brought against it.

First, there are diverse understandings as to the purpose of analytical sociology. Some maintain that the task of analytical sociology is to clarify what a good sociological explanation is in general, thus endorsing a strong normative stance which ultimately decrees what is scientific and what is not (see Demeulenaere, 2011b: 1). This position (with reason) irritates some observers (see Little, 2012a, and, partly, Gross, 2013). Others reject this imperialistic attitude and claim that analytical sociology "only provides a 'syntax' for explanation: that is to say, a set of rules on how hypotheses about mechanisms underlying the regularities of social life can be theoretically designed and empirically tested" (see Manzo, 2010: 162; see also Hedström and Ylikoski, this volume) without implying that those who do not conform with this "syntax" are *ipso facto* mistaken. Even more liberally, others claim that analytical sociology is only one of the possible ways to conduct "good" sociology, thus implying that the quest for mechanism-based explanations is not necessarily to be considered the priority (see Bearman, 2012).

Analytical sociology is also diverse with respect to some fundamental theoretical and methodological choices. Not all advocates of analytical sociology make the same assessment of the role that rational choice theory should play in model building (see Hedström and Ylikoski, this volume; Manzo, 2013b). From a methodological point of view, some of them distrust quantification and formalization (see Boudon, 2012; Elster, 2007; 2009a), whereas others consider the formal modeling of a mechanism to be a crucial research step (see Hedström and Bearman, 2009b; Hedström, 2005: Ch. 6; Manzo, 2012a).

This diversity has an advantage. Different scholars with different theoretical and methodological orientations can become interested and involved in analytical sociology. This is the success part of the story. The advantage comes with a cost, however. The heterogeneity of analytical sociology dilutes and obscures the perception of its originality. This facilitates the task of skeptical observers.

The complexity of the cognitive content of analytical sociology is likely to generate a similar twofold effect on its reception. From its very beginning, in fact, this intellectual movement has relied on a multi-dimensional combination of conceptual, epistemological, ontological, and methodological elements (see Manzo, 2010). As the topics covered by Hedström's *Dissecting the Social* show, analytical sociology requires us to reflect *at the same time* on the principles of scientific explanation, the meaning of methodological individualism, the content of the theory of action, the role of social networks, the problem of the micro–macro transition, and the advantages and shortcomings of statistical methods and formal modeling for the empirical testing of sociological theories.

These are difficult questions that bear upon some of the most fundamental aspects of social inquiry. They have long occupied philosophers of social sciences and social scientists. It is therefore not surprising that a large number of scholars have become interested in analytical sociology. This approach is seen by many as a new intellectual space in which old questions can be again addressed and hopefully developed further. At the same time, given the fundamental importance of these questions, the answers proposed by analytical sociology are likely to provoke controversies. This explains the (strong) critical reactions against the approach: in particular against some of its crucial assertions on methodological individualism and rational-choice theory (see Little, 2012a; Opp, 2013a).

The complexity of the analytical sociology research program also helps explain the criticism that it lacks originality. For assessment of analytical sociology's novelty requires the effort to consider the entire set of questions addressed and the coherence of the entire set of replies provided. What matters is the overall picture. Many of the theoretical and methodological proposals of analytical sociology have deep roots in sociology, and several areas of contemporary sociology also focus on some of them. However, the originality of analytical sociology stems from its integration of these elements into a unitary meta-theoretical framework (see Manzo, 2011a). By contrast, as the writings of the critics show, the discontents with analytical sociology systematically focus on one or only some of the components of analytical sociology's research program. They consequently neglect the source of analytical sociology's novelty: the interdependence among the elements. This is not the critics' fault. Analytical sociology is made up of a complex web of conceptual, epistemological, ontological, and methodological choices, some of which do not go undisputed even by those who are supposed to help develop the approach. Hence, it should not come as a surprise that the overall picture is still missed by many observers.

Some critics have considered this line of reasoning to be a purely rhetorical strategy whereby analytical sociology's advocates – "chameleon like," to use the expression by Lizardo (2012) – artificially mobilize new elements whenever a criticism is made. In my opinion, this interpretation is wrong. Like any research perspective that has reached a minimum level of maturity, analytical sociology is a complex intellectual construct. To cite only a few examples, Gross (2009), Goldthorpe (1998), or Back and co-authors (2012) all depict pragmatism-oriented sociology, rational-choice theory, and cultural sociology as highly heterogeneous, multi-faceted research orientations with several variants. Critical discussion of these approaches requires knowledge of their internal complexity. The same holds for analytical sociology.

Analytical Sociology: Actions and Networks has two goals. On the one hand, it aims to advance the discussion on the two theoretical pillars of analytical sociology, that is, "actions" and "networks." My concern here is to remedy the recurrent misunderstanding which views analytical sociology as a reductionist form of methodological individualism and another instance of rational-choice-based sociology. From different points of view, and with different emphases, the 15 following essays all contribute to demonstrating that analytical sociology is all about the complex interplay between "actions" and "networks" (and social structures, more generally). On the other hand, *Analytical Sociology: Actions and Networks* aims to develop the cognitive content of analytical sociology further. It does so by focusing on one specific understanding of analytical sociology's research program. The present chapter conducts detailed discussion on this variant of analytical sociology, while the remaining essays provide specific theoretical and methodological insights that help to develop and/or challenge the conception of analytical sociology proposed here. Because one of the objections brought against analytical sociology, sometimes by its own proponents (see Bearman, 2012;

Manzo, 2011a), is that programmatic statements still tend to outweigh their empirical application, virtually all the chapters contribute to the discussion on analytical sociology by studying specific empirical phenomena. This is also the case of the present essay, whose main arguments represent the meta-theoretical counterpart to empirical analyses presented elsewhere (see in particular Manzo, 2013a).

The chapter is organized as follows. In the next section, I present the set of principles constituting a particular variant of analytical sociology (Section 1.2). Each principle will then be detailed in one of the following eight sections (Sections 1.3–1.10). I summarize the main arguments in the concluding remarks section, while the final section on how to read this book gives more details about the book's orientation and content.

1.2 The principles of analytical sociology

Commentators on analytical sociology focus extensively on the epistemological features of mechanism-based explanations (compared to other types of explanation), on the concept of mechanism, on the meaning of methodological individualism, or on the theory of action defended by analytical sociologists (among the most detailed analyses, see Abbott, 2007a; Gross, 2009; Little, 2012a; Opp, 2013a). By contrast, analytical sociology's methodological proposals have been subject to only limited discussion, which has essentially focused on analytical sociology's supposedly mistaken dismissal of regression-based methods (see Opp, 2007) and on the over-importance given to simulation methods (see Lucchini, 2007: 236–240; Lucchini, 2008: 9–12; Winship and Morgan, 2007: 233, note 10).

This imbalance is problematic because analytical sociology is in fact a set of research guidelines for both theoretical model building and empirical model testing in sociology. Hence, the meaning and the scope of analytical sociology can only be appreciated if the approach is understood as the intersection between one set of principles concerning the construction of explanatory theoretical models and another set of principles referring to the empirical validation of those models.

Without a doubt, this characterization is insufficient to set analytical sociology apart from other research traditions that also seek to devise conceptual models and to prove their empirical appropriateness. To a large extent, this is the purpose of all scientific research. The specificity of analytical sociology should thus be sought in the distinctive way in which its model-building and testing practices are conceived and concretely organized. I suggest that analytical sociology's uniqueness within contemporary sociology can only be fully appreciated if the following combination of principles (hereafter, P) is considered (for a graphic illustration, see Figure 1.1):[1]

- P1: use concepts that are as clear and precise as possible to describe both the facts to be explained and the explanatory hypotheses/facts mobilized to explain them, while avoiding all linguistic obscurity and convolutedness;
- P2: mobilize the best quantitative and qualitative empirical information available and use the technical tools best suited to describing the facts to be explained;
- P3: in order to explain the social outcome(s) described, first formulate a "generative model," that is, a model of a (set of) mechanism(s), where a mechanism is a set of entities and activities likely to trigger a sequence of events (i.e., a process) likely to bring about the outcome(s);

[1] Figure 1.1 develops Figure 3 in Manzo (2007c).

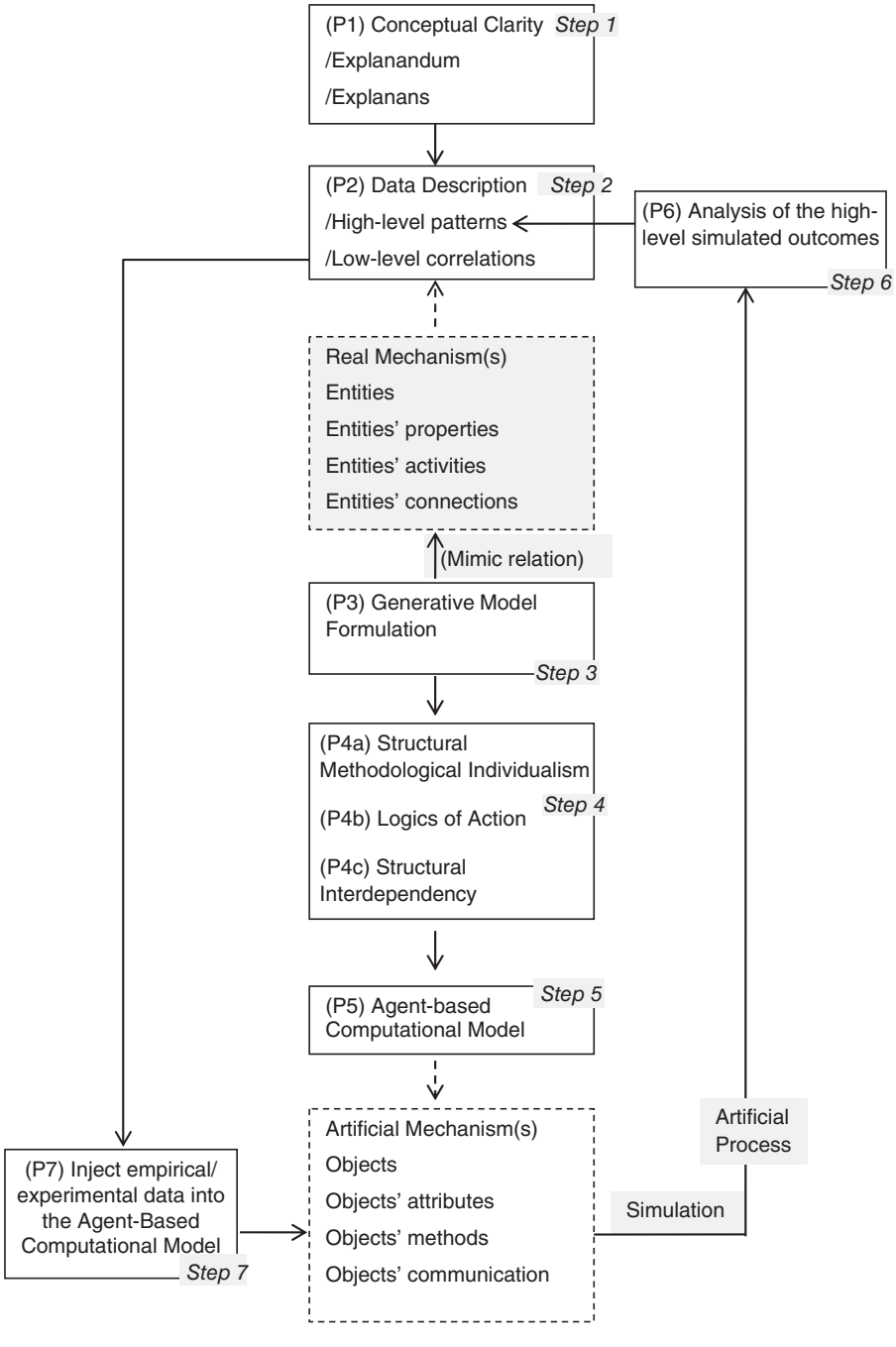


Figure 1.1 Stylized ideal–typical research cycle underlying analytical sociology.

P4: in order to formulate the "generative model," provide a realistic description of the relevant micro-level entities (P4a) and activities (P4b) assumed to be at work, as well as of the structural interdependencies (P4c) in which these entities are embedded and their activities unfold;

P5: in order rigorously to assess the internal consistency of the "generative model" and to determine its high-level consequences, translate the "generative model" into an agent-based computational model;

P6: in order to assess the generative sufficiency of the mechanisms postulated, compare the agent-based computational model's high-level consequences with the empirical description of the facts to be explained;

P7: in order to prove that the hypothesized micro- and network-level assumptions are not only generative sufficient but also empirically grounded, inject as much individual- and relational-level quantitative, qualitative, and/or experimental data as possible into the agent-based computational model and reanalyze its behavior and high-level consequences.

If one considers that the facts of primary interest to analytical sociology are cross-sectional population-level patterns and their temporal trends (see Hedström, 2005: 67), then P1–P7 turn analytical sociology into an empirically oriented, experimentally and computationally based, macro-sociology with clearly explicated and empirically grounded dynamic micro- and network-level foundations.

Before I discuss each principle in detail, let me clarify how, in my opinion, these principles should be understood, and what we may gain from conceiving analytical sociology in this axiomatic form.

In regard to the meanings of P1–P7, it would be a mistake to interpret them as a set of universal normative imperatives. Figure 1.1 should not be understood as describing a rigid sequence of research steps that must necessarily be followed. Sometimes a researcher does not have the time, resources, and/or cognitive skills to meet the requirements contained in the seven principles. Sometimes, the researcher may refer to the results of previous studies of relevance to one (or some) of the research step(s), thus directly implementing only a subset of the operations proposed. Hence, P1–P7 should be regarded as a set of logically organized guesses as to the fruitfulness of a specific list of theoretical and methodological options. This is a set of guesses that should be borne in mind even if it is not possible or not necessary to perform all the requisite operations within a given piece of research. This is the sense of what Lakatos (1972: 132) considered a "research program," that is, a set of "methodological rules: some tell us what paths of research to avoid (negative heuristics), and others what paths to pursue (positive heuristics)."[2]

[2] It is important to stress that this set of rules is not imposed a priori. Contrary to what some critics assert, analytical sociology does not claim that "in sociology the meta-methodological enlightenment has come first (in the form of AS [Analytical Sociology]) and the practice has followed (or should follow, because apparently only the enlightened few practice it properly)" (see Lizardo, 2012: 9). Hedström (2005: 6–9), Hedström and Bearman (2009b), Hedström and Udehn (2009), and Manzo (2007a; 2010: 132–138) show that analytical sociology's proposals build on existing theoretical ideas and empirical studies. For instance, the book *Education, Opportunity, and Social Inequality* by Boudon (1974) is a good example of an empirically oriented study that contains in practice many of the ideas underlying P1–P7. Today's analytical sociology stands "on the shoulders of giants" but attempts to codify their intuitions and elaborate them further partly in light of recent advances in philosophical debates and partly by drawing on new methodological developments.

Although specific, this conception of analytical sociology as a research program defined by P1–P7 has, in my opinion, three general advantages.

First, listing the principles sequentially, from the most general (P1) to the most specific (P7), helps to assess analytical sociology's uniqueness within contemporary analytical sociology. Indeed, as the number of principles considered increases, their combination makes it increasingly difficult to find one sociological perspective defined by the same combination of elements. The initial apparent overlap between analytical sociology and the rest of sociology thus tends progressively to disappear (on this point, see also the concluding remarks section).

Second, P1–P7 allow the better mapping of analytical sociology's internal heterogeneity. The main dividing line seems to be between those who accept the entire set of principles and those who restrict analytical sociology to P1–P4, plus the application of P7 without formal modeling, thus rejecting the idea that formal modeling is necessary to prove that there is a real connection between the explanans and the explanandum. In this regard, the description by Hedström (2005: 143–144) or Hedström and Bearman (2009b: 16) of analytical sociology's core research strategy differs markedly, for instance, from the non-formalized but deep explanatory analyses contained in Gambetta (2009).

Third, P1–P7 help to visualize why analytical sociology needs its own internal heterogeneity, other theoretical and methodological sociological perspectives, as well as specialties lying outside sociology. Going from P1 to P7 is extremely demanding in terms of time and cognitive resources. Even the best equipped scholar may be unable to fulfill all the requirements contained in the seven principles in a single piece of research. Thus, P1–P7 provide guidelines with which to locate potential collaborators within and outside sociology, and they suggest research areas that can help with developing some or other item on the analytical sociology research program.

This is the spirit that animated the selection of essays collected in *Analytical Sociology: Action and Networks*. While only a few chapters approximate the full research cycle depicted by Figure 1.1 (see the contributions by Gabbriellini, Grund, and Fountain and Stovel), all of them show how analytical sociology communicates with, and benefits from, other research traditions – like game theory, social network analysis, cognitive psychology, or behavioral economics – and how studies implementing only some of P1–P7 at a given point in time may help create the conditions for complete application of the research program in the long run. It is this conception of analytical sociology as a constantly evolving web of elements that we may want to pursue and develop further. *Analytical Sociology: Action and Networks* modestly seeks to contribute to this endeavor.

1.3 Clarity (P1)

Within analytical sociology, P1 – the quest for clarity and precision in the definition of concepts and in writing style – has evident philosophical roots (see Hedström, 2008: 331–302). In particular, it stems from one of the axioms of analytic philosophy that the ambiguity of natural language is responsible for many conceptual problems and misleading observations (for a thorough survey of analytic philosophy, see Glock, 2008). From the point of view of an empirically oriented discipline, this implies that both the concepts describing the facts to be explained and the facts mobilized to explain them must be formulated in clear and simple terms. Otherwise, analytical sociologists argue, the

connections among events are difficult to see and the empirical testing of competing theoretical hypotheses is difficult to perform.

Building on Pareto's distinction between a theory's ideological utility and its empirical descriptive accuracy, Boudon (2002: 375, emphasis added) noted: "A false and useful theory is often perceived as true, as long as its falsity is not too visible. If in addition it is *obscure*, it may even be perceived as *profound*." Analytical sociology's P1 aims to avoid this undesirable cognitive effect. P1 relies on the conviction that the complexity of social reality does not require linguistic complexity to be described. Analytical sociology thus rejects the equation between linguistic intricacy and intellectual profundity.

The macro-consequences of linguistic convolutedness have been specified by Sperber (2010). What he labels the "Guru Effect" corresponds to a causal chain that can be summarized as follows. Interpreting linguistically complex and convoluted sets of sentences is demanding in terms of cognitive effort. When, despite the efforts made, the reader is still unsure about the meaning of the argument, s/he looks for external cues to adjudicate on it. External signs of academic authority and reputation often serve as such cues. The larger the author's stock of such signs, the more likely it becomes that the reader will conclude that his/her lack of understanding reflects the profundity of the author's thought rather than author's lack of clarity. This belief may be reinforced by the interdependence of actors' beliefs. In search of external cues, the reader may look at the opinions of other readers, who, under pressure of the same cognitive mechanism, will tend to endorse the same belief as the focal reader's. Actors' beliefs thus dynamically reinforce each other. The reader's confession to others of his/her lack of understanding puts the reader in a potentially embarrassing situation which generates a "spiral of the silence" that may fuel an explosion of intellectual credibility for authors and articles.

There are consequently good reasons to pursue conceptual and linguistic clarity. Indeed, it is likely that linguistic convolutedness increases the probability that undesirable intellectual dynamics – in which hermeneutic problems become more central than the analysis of specific empirical facts – will arise, with a consequent waste of cognitive resources: namely, the resources needed to eliminate false debates and unjustified academic authorities from the academic market of ideas.

That said, P1 is certainly not sufficient on its own to confer originality on analytical sociology. Elster (2007: 455), for instance, considers the "near-obsessive concern with clarity and explicitness" to be the distinctive feature of "the analytical turn" that he sees at work in the social sciences at large. Thus, one may agree with those discontents of analytical sociology who have claimed that "clarity and precision"

> is certainly sufficient to tell AS apart from the mass of sociological research that is unclear and imprecise (or from bad translations of French theory), but it certainly does not work well to make it different from the equally large mass of sociological research that is in fact clear and precise.
>
> (Lizardo, 2012: 7)

However, the problem with this objection is that it isolates the clarity requirement from a larger set of principles. As I have argued above, it is the combination of these principles that matters when one wants to assess the intellectual distinctiveness of analytical sociology.

1.4 Description (P2)

When the explanandum is formulated in clear and explicit conceptual terms, it is easier to find appropriate empirical indicators for it. This facilitates the application of the second key principle of analytical sociology: that the facts to be explained should be precisely identified by mobilizing the best empirical information available and by using the technical tools best suited to describing the data.

In this respect, analytical sociology has two general ambitions. First, it wants to foster the development of new data collection procedures in which an explicit connection is established between the social mechanisms that one wants to study and the data collection design (see Hedström and Swedberg, 1996: 136–137). Second, analytical sociology wants to stimulate the more creative use of descriptive data (see Brückner, 2009). As testified by the essays collected in this book, the first goal induces scholars not to restrict the kind of empirical data that can be mobilized to describe the social outcome(s) of interest. Individual-level survey data (see Chapter 4), aggregate, historical administrative, and census data (see Chapters 6 and 14), geo-referenced data (see Chapter 3), video-recorded data (see Chapter 3), textual data (see Chapter 5), network-based data (see Chapters 6 and 12), digital, Web-based data (see Chapters 10, 13, and 16), and experimental data (see Chapters 7, 8, and 15) are regarded as equally relevant sources of empirical information with which to describe the facts to be explained. On the other hand, when empirical data are wrung in order to tackle the empirical signature of the individual- and network-level mechanisms at work, analytical sociology combines different types of data within the same study (see Chapters 3, 6, and 8).

The importance that analytical sociology attributes to descriptive tasks warrants special treatment because it is not always properly understood. Some commentators, indeed, have criticized the analytical sociology research program for what they consider to be its excessive and unjustified emphasis on explanatory goals (see Reiss, 2007: 164; Opp, 2005; Pisati, 2007). More explicitly than others, Bernardi (2007: 3, my translation from Italian) notes that "acknowledging the importance of description makes us aware of the risk of lapsing into what one may call 'mechanismism', that is, the obsessive quest for mechanisms behind phenomena that are not well defined and the existence of which is not well established."

Two factors help explain this misperception of analytical sociology. First, it is true that there is some variability within the analytical tradition concerning the virtues of description. While Boudon (2002) explicitly distinguished between "scientific" and "descriptive" sociology – thus giving the impression that description can only play a secondary role within scientific research – Hedström and Swedberg (1998b: 17) made it explicit that "we do not wish to suggest that quantitative empirical research is of minor importance for the sociological enterprise. Quite the contrary: Quantitative research is essential both for descriptive purposes and for testing sociological theories." More recently, Bearman (2012: 2) has provocatively declared:

> Good sociology often involves explanation but I think good sociology can also be in the business of description without any explanation at all. . . . Some of the richest descriptions of things are those things that cannot be seen or known by individuals. And when those are described, I think we get some pretty good sociology.

Thus, according to the authors that one decides to consider more persuasive, analytical sociology may or may not be accused of privileging explanation over description. In my opinion, the important point is that it is not possible to explain something that has not been previously empirically described (see Goldthorpe, 2004). As a consequence, the most convincing position seems to be the one that gives equal importance to description and explanation and considers these tasks to be different steps in a more general research process – which is the meaning of the ordering between P2 and P3.

That said, there may be a more fundamental reason why some commentators see analytical sociology as a potential threat to description. This reason has to do with analytical sociology's critical assessment of the scope of multivariate statistical methods (see Hedström and Swedberg, 1998b: 15–17; Hedström, 2005: Ch. 5). The thrust of the criticism is expressed by Hedström (2005: 113) as follows: "causal explanations are not achieved by simply estimating parameters of generic statistical models, but by developing evidence-based generative models that explicate the mechanisms at work." The crucial point here is that no matter how carefully the variables entering a statistical model are chosen; no matter how resistant the structure of the model's estimates is to different model specifications; no matter how large the amount of outcome variability accounted for by the predictors' variability – the model's coefficients cannot provide a detailed representation of the entities, the activities, and the relations among those entities and activities that are likely to be responsible for the observed outcome(s).

However, as testified by the above quotation from Hedström and Swedberg, it would be a mistake to equate this critical stance with an extreme, final dismissal of variable-centered statistical analysis (see also Brante, 2008). Analytical sociologists are perfectly aware that statistics is a powerful tool with which to figure out robust relations among factors measured at, and referring to, different levels of analysis. As P2 suggests, performing or referring to this kind of analysis is the first step in any serious mechanism-oriented analysis. Moreover, as my discussion of P7 will suggest (see Section 1.10), robust relations among context-, network-, and individual-level variables can be employed to increase the realism of formal, explicit models of social mechanisms. The argument among analytical sociologists, therefore, only concerns the scope and the appropriate task that can be legitimately attributed to multivariate statistical methods. No matter how carefully specified and sophisticated a statistical model may be, it can only provide a parsimonious description of a set of relations that represents the individual- or social-level signature of a (set of) social mechanism(s). But it cannot provide an explicit, detailed, and dynamic representation of that mechanism and of its high-level consequences (for a detailed application of these criticisms to a specific statistical technique, namely log-linear topological models, see Manzo, 2006).

It should be acknowledged that analytical sociology's critical assessment of variable-based analysis has long-standing roots in sociology (see Boudon, 1979; Sørensen, 1976) and in philosophy of social sciences (see Harré, 1972: 118). Among contemporary authors, scholars as different as Abbott (1988; 1992; 1997), Abell (2004), or Goldthorpe (2001) have also raised similar objections against regression-based methods. Statisticians like Freedman (1991; 2005) or Cox (1992) have urged resisting the temptation to interpret statistical coefficients as revealing underlying causal mechanisms.

Once again, however, analytical sociology's principles should not be assessed in isolation. The role that P2 attributes to description and to variable-centered analysis should be read in combination with the proposals contained in P5–P7. As we shall see, these principles attempt to build a complex interface between statistics and substantively oriented formal modeling

which constitutes the constructive side of analytical sociology's critical stance toward variable-centered sociology (see also Manzo, 2007a).

1.5 Generative models (P3)

While the rigorous (variable-based, when appropriate) empirical description of the social regularities to be explained is a fundamental task for analytical sociologists, P3 clarifies that description is only the first, preliminary step along a more complex research path whose core consists of explanation (see Figure 1.1).

From the point of view of philosophy of science, this explanatory ambition seems entirely legitimate (see Hempel, 1965: 245). However, given that a variety of understandings of how an explanation can be provided exist in social sciences (see Little, 1991) and that different explanatory modes co-habit within the ordinary and the academic world (see Mantzavinos, 2013), the specific conception of explanation that analytical sociology defends is likely to arouse resistance. In particular, within analytical sociology, explanation is understood as a model-based, mechanism-seeking activity. Let me first briefly discuss the concept of mechanism, and then explain the meaning of the "model-based" label.[3]

While the concept of mechanism has received a variety of definitions (for a collection of them, see Mahoney, 2001: 579–580; Gerring, 2008; Gross, 2009: 360–362; Hedström, 2005: 25; Hedström and Bearman, 2009b: 5–6), two simple ideas may be used to understand it. In terms of epistemic function, a mechanism is meant to make sense of the connection observed between (at least) two happenings. In this sense, a mechanism aims to eliminate black-box input/output relationships (see Bunge, 1997; Boudon, 1998a; Hedström and Swedberg, 1998b). In terms of content, by adapting a definition from biology (see Machamer, Darner, and Craver, 2000), a mechanism can be conceived as consisting of a set of organized entities whose properties and activities are able to trigger changes that generate the observed connections with some regularity.

It is essential to appreciate that the concept of mechanism is substantively empty. The specific entities, properties, activities, and connections, as well as the particular nature of these activities (for instance, probabilistic versus deterministic), should be defined only in connection with the specific outcome under scrutiny and in relation to the specific level of analysis at which the outcome is observed. It is for this reason that it is so difficult to find a consensual dictionary definition of the concept (see Hedström and Ylikoski, this volume). This analytical property should be regarded as an opportunity. The substantive emptiness of the concept of mechanism allows it to travel across the natural and social sciences, as well as across their research subfields, thus potentially enhancing knowledge accumulation, communication, and understandability. To borrow a concept from the

[3] As the recent exchange between Opp (2013b) and Ylikoski (2013) suggests, it seems that the debate on explanation (in sociology) can be advanced if we frame the problem in terms of "epistemic compatibility" among several explanatory modes rather than as a conflict among them. By "epistemic compatibility" I mean the possible co-existence within a given explanation of elements that at first glance seem typical of a specific explanatory mode. As my discussion will show implicitly, when one builds a model of a mechanism, one partly relies on correlational elements, and when one studies the model (by simulation), one implements a deduction. Thus, mechanism-based explanations share elements of other explanatory modes, namely variable- and law-centered explanations. As I shall seek to show, this is perfectly compatible with the claim that mechanism-based explanations have their own specificity and that there are good reasons to regard them as more profound in terms of explanatory detail.

sociology of science and technologies, a mechanism can be conceived as a "generic instrument," that is, a (conceptual, in this case) device based on principles that can be adapted to different application domains and thus be reshaped again and again (see Shinn, 2008).[4]

It is also important to understand why a mechanism should not be equated with an intermediate/mediating variable (see Pawson, 1989: 130–131). From an epistemic point of view, the introduction of intermediate/controlling variables has the purpose of checking for the possibility that the order-zero relation is accounted for by elements that were not considered initially. In this sense, this operation aids understanding of the origin of the order-zero relation, and it echoes the goal of eliminating black-box input/output relationships, which also is the epistemic feature of guessing a mechanism. However, the content of a mechanism shows why this similarity is only apparent. The set of intermediate/controlling variables introduced does not amount to a set of entities, properties, activities, and connections that may be responsible for the social production of the order-zero relation. At best, these variables are fragmentary indicators of that underlying, potentially generative structured system. To give an example, a path-analytical diagram is indubitably able to dissect the (average) order-zero relation between, say, the occupations of parents and the final occupations of their offspring, hence increasing our initial understanding of the relation between the two variables. But the set of additional variables progressively introduced into the model only provides a remote (average) statistical signature of the underlying mechanism, which is likely to be made up of interacting actors and organizations with their own goals and opportunities.

Hence, one should be wary of statements like these: "Anyway, it is important to note that mechanism-based explanations are complex relationships between variables, which ultimately (i.e., on the micro level) are properties of actors" (Opp, 2007: 121) or

> The appeal for mechanisms is a useful rallying cry, but the originality of a mechanism-based sociology has been oversold. . . . Arguing that mechanisms are concatenations of nonlinear functions is not an argument against the use of variables, since the primitive elements of functions – defined as inputs and outputs – can be redefined as variables.
>
> (Morgan, 2005: 31)

These considerations on mechanism-based explanations make an important point explicit: the need for data structures and operations on these data structures to operationalize a theoretical representation of a (set of) mechanism(s). This is especially apparent when mechanisms are studied by means of formal modeling (see Section 1.9). However, the role performed by (numerical and logical) variables and functions relating and operating on these variables within a (formal model of a) mechanism is radically different from that of variables within a statistical model. While a formal model of a mechanism uses variables and functions to mimic the details of entities' properties and activities, and of connections among entities, with the aim of making these entities trigger changes over time that in the end may bring about the connection under scrutiny, variables and functions are used within a statistical model to detect a pattern of average effects which may reflect the (aggregate) statistical signature of the (unspecified) underlying mechanism. For this reason, while it is correct to say

[4] I will elaborate more on this idea in the book's general conclusion.

that the detailed theoretical representation of a mechanism entails the use of variables and functions, the main implications that some draw from this fact – that structured sets of intervening/mediating variables can be considered "mechanism sketches" (see Morgan and Winship, 2007: 238–242) and that multivariate statistics can be used to test mechanism-based explanations directly (see Opp, 2007: 121) – fail fully to appreciate the different functions and contents of variables and mechanisms.

That mechanism-based explanations imply (unexplained) relations among variables has been used to attack the explanatory modes advocated by analytical sociology also from a different perspective. Some have argued that the epistemic function of a mechanism, that is, to eliminate black-box input/output relationships, entails the empirical inapplicability of this explanatory mode because, given the infinite causal intricacy of the natural and the social world, any posited mechanism mobilized to explain a given observed connection necessarily relies on some connections that are unexplained in terms of mechanisms (see Opp, 2005: 169; Steel, 2004: 61–64; Pisati, 2007: 7).

On purely logical grounds, this objection is convincing. In practice, two considerations should be borne in mind. First, the "generative" conception of the causality behind mechanism-based explanations (on the concept of "generative" causality, see Harré, 1972: 116, 121, 136–137) does not seem to be the only understanding of causality exposed to this kind of fallacy. To use the terminology in Goldthorpe (2001), causation as robust dependence can be criticized because it is logically impossible to be sure that all confounders have been taken into consideration, whereas the conception of causation as consequential manipulation is logically flawed by the fact that it is impossible simultaneously to observe the treatment's effects and the absence of the treatment on the same subjects. Similarly, the counterfactual understanding of causation (see Woodward, 2002) may be attacked on the grounds that it is in principle always possible to find one counterfactual that has not been checked. The fact that different conceptions of causal explanation are exposed to very similar objections suggests that the objection at hand may be related to the asymmetry that exists between the causal complexity of reality and our limited capacity to grasp that complexity. Thus, the second element that the "infinite regression" objection does not seem fully to appreciate is the inescapable, historically grounded nature of the mechanism-based explanatory mode. The final nature of a mechanism-based explanation of a given connection is always relative to the existing explanations of this connection and to the current conventional nature of disciplinary and subdisciplinary boundaries (see Hedström and Swedberg, 1998b: 10; Hedström, 2005: 27; see also Hedström and Ylikoski, this volume).[5]

The progressive, historically rooted nature of the analysis of causal mechanism allows one to see why the mechanism-based explanations sought by analytical sociology are at the same time model-based explanations. Even with respect to the connection(s) that one wants to study in detail, it is indeed impossible to take into account all the complexity of the mechanism(s) at work. While one is required to make the effort to formulate realistic guesses as to the entities, properties, activities, and connections at work (see Hedström, 2005: 62–63; Hedström and Ylikoski, this volume), abstraction, that is, the capacity to ignore secondary details, is a fundamental epistemological guideline for building mechanism-based explanations (see

[5] As Elster (1983: 24) remarked: "From the standpoint of either scientific investigation or philosophical analysis it can fairly be said that one man's mechanism is another man's black box. I mean by this that the mechanisms postulated and used by one generation are mechanisms that are to be explained and understood themselves in terms of more primitive mechanisms by the next generations."

Hedström and Swedberg, 1998b: 24–25; Hedström, 2005: 2–3). As a consequence, analytical sociology's explanatory activity is based on models of mechanisms, not on mechanisms themselves. The model is regarded as the cognitive and methodological tool which makes it possible to establish a mediation between the observer and reality, thus enabling the former to handle the complexity of the latter (on the understanding of models as "mediating instruments," see Morgan and Morrison, 1999).

I suggest the term "generative models" to denote a set of theoretical hypotheses making theoretically and empirically informed guesses on the set of entities, properties, activities, and connections potentially responsible for a given observed connection of interest (for earlier definitions of this concept, see Boudon, 1979; Fararo, 1969; Schelling, 1978: 89).

The concept of "generative model" should help avoid a common misunderstanding. Some commentators, in fact, have complained about the ambiguous status of the concept of mechanism: is it a theoretical proposition or does it represent an in-world operating device (see Brante, 2008: 276; Mayntz, 2004: 239; Reiss, 2007: 166)? The distinction between the concept of mechanism and that of "generative model" helps clarify that mechanisms are "parts" of the social world, not mere theoretical constructs. What is instead theoretical is the set of hypotheses built to mimic the mechanism, that is, the "generative model." Analytical sociology is all about the construction of "generative models" and their empirical testing.

Is this sufficient to claim the distinctiveness of analytical sociology? Historically, one may argue, implicit mechanism-based explanations can already be found in Tocqueville (Cherkaoui, 2005: Ch. 1; Elster, 2009b; Edling and Hedström, 2009; Swedberg, 2009), in Marx (Elster, 1985), in Weber (Cherkaoui, 2005: Ch. 2), or in Durkheim (Cherkaoui, 2005: Ch. 3; Fararo, 1989: 134–137). On the other hand, at least since the early 1990s, the concept of mechanism-based explanation has been at the center of diverse discussions in philosophy of the natural (Glennan, 2002; Woodward, 2002) and social sciences (Bunge, 1997; 2004; Little, 1991; Manicas, 2006); it has generated considerable debate in political science (Gerring, 2008; McAdam, Tarrow, and Tilly 2008; Tilly, 2001) and in comparative historical sociology (Kiser and Hechter, 1991; 1998; Mahoney, 2004; Sica, 2004); and explicit programmatic statements in favor of a "generative" epistemology can be found in political science (see Cederman, 2005) and in economics (see Epstein, 2006).

Analytical sociologists are aware that they are part of a wider scholarship elaborating on the concept of mechanism (see Hedström and Ylikoski, 2010; Manzo, 2010). They only maintain that, within contemporary sociology, analytical sociology is making the greatest theoretical and methodological effort to elaborate the concept of model-based, mechanism-seeking explanation in an *explicit* and *systematic* way (see Hedström and Ylikoski, this volume). Once again, in order properly to assess this effort, P3 should not be isolated from the entire set of principles in which it is logically embedded.

1.6 Structural methodological individualism (P4a)

P3 clarifies that analytical sociology's explanatory activity is all about the construction of "generative models." But what is the prototypical, generic structure of a generative model? P4a–c complete P3 by specifying that a generative model should contain three basic

elements (see Figure 1.1): (1) a realistic description of the relevant micro-level entities at work (P4a); (2) a realistic description of their properties and activities (P4b); and (3) a realistic description of the structural interdependencies that are likely to relate these entities (P4c). In the present section, I focus on P4a (micro-level entities) while leaving the discussion of P4b (i.e., activities) and P4c (i.e., structural interdependencies) for the two next sections.[6]

Analytical sociology's generative model-building activity is committed to methodological individualism. Actors and their actions are regarded as the causally relevant micro-level entities of social life in the sense that, to resume Hedström's provocative counterfactual, "if we were able to press a pause button that suddenly froze all individuals and prevented them from performing any further actions . . . all social processes would then come to an immediate halt" (Hedström, 2005: 28). As demonstrated by Udehn (2001), however, this postulate has received several interpretations in the history of the social sciences. Since critics of analytical sociology have extensively commented on the supposedly reductionist stance adopted by analytical sociologists (see Abbott, 2007a; Sampson, 2011; Sawyer, 2011; Little, 2012a), it is important to discuss carefully the form taken by the postulate of methodological individualism within analytical sociology. I will argue that this form is complex, and that it conceives "structures" and "actions" as related by a dynamic relation of co-determination (see also Manzo, 2007b; 2012b).

Let us start with the following statement: "Verbally, we can say that phenomenon M is a function of actions m, which are dependent on situation S of the actor, which situation is itself affected by macro-social conditions M" (Boudon, 1986: 30).

Boudon's formulation provides us with a simple description of the so-called "structural individualism" originally proposed within Dutch sociology in overly anti-reductionist terms (Wippler, 1978: 143). This form of methodological individualism conceives actors and their actions as embedded in a dense web of contextual and relational interdependencies. As stressed by Hedström and Bearman (2009b: 4, 8), "structural individualism differs from traditional methodological individualism in attributing substantial explanatory importance to the social structure in which individuals are embedded" and "by emphasizing the explanatory importance of relations and relations structures." Thus, the objection that analytical sociology is based on a "reductionist strategy" according to which a "good explanation . . . should not make reference to meso or macro level factors" (see Little, 2012a: 3) is simply factually wrong.

Boudon's definition of structural individualism also highlights a second crucial point. Not only are macro- (e.g., the electoral system) and meso-level (e.g., a given political party) entities and properties (e.g., a collective party's position on a given issue) legitimate ingredients of the explanation, but also, once they come into existence, they are assumed to have causal effects on the properties and activities of the micro-level entities (e.g.,

[6] By "prototypical" structure, I mean the set of elements that analytical sociology regards as foundational when a generative model is to be built to explain given high-level *phenomena* like inequality patterns, network topologies (among actors or organizations or both), norms and collective beliefs, organizational and group dynamics. By "generic" structure, I signal that the details of these elements, as well as the weight given to each of them, will depend on the specific (aspect of the) high-level outcome on which the analysis focuses.

individual voters). This is nicely described in dynamic terms by Coleman (1993: 63) when he posits that

> structure at one time (macro-level) generates the conditions which together with existing interests shape the actions of actors (micro-level) that jointly produce outcomes which modify the structure of a later time (macro-level) which generates conditions that again (through constraints and incentives) shape actions (micro-level) that jointly produce outcomes (macro-level) and so on.

Thus, macro- and meso-level entities and properties are regarded as causally important by analytical sociologists. From an explanatory point of view, the only requirement is that it should be possible to indicate at least one micro-level element through which the macro/meso-to-micro causal effect is generated – no matter if consciously or unconsciously from the point of view of the micro-level entity at hand (see Hedström and Bearman, 2009b: 11). This is the meaning of the concepts of "situational" mechanism (Hedström and Swedberg, 1998b: 21–22) and of "bridge" hypotheses (Esser, 1998).

Coleman's depiction of the dynamic relation between structure and action also suggests that the form of methodological individualism behind analytical sociology is entirely compatible with the idea that macro- and meso-level properties can be emergent with respect to the micro-level properties and activities that have contributed to their production (for a detailed overview of the concept of emergence, see Sawyer, 2005: Ch. 5, in particular).

By "emergent" I mean that some of the macro- and meso-level properties generated by the activities of a set of micro-level entities at time *t* have three empirical features: (1) once they come into existence, these properties span a temporal window wider than that characterizing the micro-level entities that have contributed to generating them; (2) once they have come into existence, these properties cannot be meaningfully defined, nor quantified, for a single micro-level entity (on this second feature, see Hedström, 2005: 67; see also Hedström and Ylikoski, this volume); and (3) the specific value and form assumed by these properties crucially depends on the system of interdependencies that exists among the set of micro-level entities. Patterns of educational inequality (or other forms of social inequality) are good examples of macro-level structures that are emergent in this sense. Indeed, while the actions and the interactions of a given cohort of students with different social backgrounds contribute to distributing those students within the hierarchy of educational levels available, the specific configuration of this distribution, as well as its amount of inequality, cannot be entirely anticipated on the basis of the students' properties alone – that is, without taking the interdependencies among students into account – and once it has come into existence, its shape and inequality last longer than the students who have contributed to generating it; nor can it be referred to one of those students in particular (for a rigorous analysis of this statement, see Manzo, 2013a).

Thus, contrary to what some have argued (see Sampson, 2011), the framework of structural individualism on which analytical sociology is built is able to handle the analysis of macro- or meso-level emergent entities and properties. When properly understood, the dynamic loop between structure and action posited by Coleman (see the above quotation) implies that structural properties are emergent (in the above-defined sense). If not, if structures evaporated as soon as their micro-level bases were modified, it would be

impossible to posit, as Coleman does, that the new structure would causally constrain later actions.[7]

The last major point to address concerns the extent to which structural individualism admits connections among macro- and meso-level emergent (in the above-defined sense) entities and properties. According to a recurrent objection, analytical sociology is limited by the fact that structural individualism does not regard as legitimate any form of macro-to-macro or meso-to-meso causal explanation: that is to say, explanations of "one set of factors in terms of another set of factors at the same level" – what Little calls "lateral strategies" (Little, 2012a: 21; see also Little, 2012b).

In this regard, let me quote Boudon (1998a: 172–173):

> Theories of SMs [Social Mechanisms] that do not belong to the MIP [Methodological Individualism Paradigm] can exist and be useful. Thus it can be useful to observe that in given circumstances inflation has a positive effect on employment, or that suicide rates decrease during severe political crises, even if we are not able to make these theories final. They lead, namely, to further questions: Why is that so? Under which circumstances do the effects occur, and so forth? But we may be unable to answer them. So SMs and MIP imply each other only to the extent to which final theories are aimed.

Boudon's statement clearly acknowledges the legitimacy of macro-to-macro and macro-to-meso connections. Analytical sociology only claims that "lateral strategies" are unable on their own to provide details on how the macro-to-macro or meso-to-meso connection at hand came into existence. In this regard, those who argue in favor of the causal nature of these connections usually fail to provide any compelling example of a mechanism that leads from a given meso-level factor A to a given meso-level factor B "without proceeding according to the logic of Coleman's boat – up and down the struts," to quote from Little (2012a) (see also Jepperson and Meyer, 2011; Sampson, 2011). The opposite is true. For instance, when Little (2012a) discusses five pathways through which "meso-level structures have causal powers" (he focuses on organizations in particular), all of them amount to a detailed

[7] Once this is understood, it is unclear what the objections by Gorski (2008: 176–181) to Hedström, and analytical sociology more generally, amount to. He finds it inconsistent that a two-layered social ontology is posited in practice while a stratified vision of social reality is rejected on principle (Hamlin, 2002: Ch.1 addressed a similar objection to Boudon). The misunderstanding probably arises from the fact that although structural methodological individualism posits a circular relation between "structure" and "action," it does not in fact assume a "two-layered ontology." Let me address this point on the basis of an example. Take formal rules like law. Without a doubt, laws result from complex negotiation processes among several actors, so that in the end, once a given formal rule has come into existence, it does not entirely reflect the action of any specific actor that has contributed to generating it. In this sense, formal rules are "emergent." Once they have come into existence, they also physically exist in written form in law treatises. In this sense, formal rules are "real." But, to produce further effects, formal rules need to be in actors' minds. A given actor can be influenced by a formal rule either because s/he takes it consciously into consideration or because s/he learnt it in the past, thus being now unconsciously subject to its effect; or, another option, because a third party uses the formal rule to change the focal actor's state. In this sense, formal rules are not "real" on their own. They exist because they exist in actors' minds. Rule-to-rule connections can indubitably also be observed: think of when the elimination of one rule makes another rule inapplicable (because rules often form a system). But, again, this connection does not exist on its own; it does so only because actor-level actions of some kind have been realized to create it (earlier than or concomitantly with the observed norm-to-norm change). Thus the real problem is knowing what "real" really means for those who ask analytical sociology to postulate something more than what structural methodological individualism already postulates.

description of how micro-level properties like individuals' beliefs, values, desires, incentives, or identities are shaped by the specific organizational and institutional settings at hand. The fact that, as Sampson (2011: 238) argues, a given high-level entity's properties may change without any modification in the micro-level entities composing the high-level entity does not prove that the change in the high-level entity is, directly or indirectly, unrelated to the properties and activities of some other remote micro-level entity.

To sum up, the foregoing discussion suggests that, when properly understood, structural methodological individualism can handle: (1) macro- and meso-level entities and properties; (2) downward causation; (3) macro-level emergence; and (4) macro-to-macro and meso-to-meso correlations. Thus, analytical sociology posits something more refined than "non-controversial, trivial statements" such as "individuals are the primary entities and their actions are the primary activities in social mechanisms" (Lizardo, 2012: 5). At the same time, it does not postulate at all that "explanations have to bottom out in some 'reductive' account of individual action" (p. 5). The core theoretical proposal behind structural methodological individualism is that "structure" and "action" are related by a dynamic, circular relation that should be broken down analytically precisely in order to explain how a given high-level connection came into existence. Within the history of methodological individualism (see Udehn, 2001), this is far from being the most frequent position. Compared to other theoretical approaches with which analytical sociology shares a similar concern for the circularity of the relation between "structure" and "action" – consider the "morphogenetic" approach of Archer (1995), the "structuration theory" of Giddens (1984), or the "genetic structuralism" of Bourdieu (1990) (for an overview of late developments, see Freré, 2011) – analytical sociology's distinctiveness consists of its attempt to give fine-grained, dynamic accounts of this relation, not in general, but in the context of specific, socially and historically located, macro-level regularities.

1.7 Logics of action (P4b)

Once it has been posited that the "prototypical," generic form of a generative model should provide a theoretical guess as to the micro-level bases of the high-level regularities under scrutiny, the next step is to specify the kind of "activities" that the micro-level entities (actors, in our case) are assumed to perform. This raises the question of the "logic of action" to be selected in order to construct a generative model (see Figure 1.1, P4b).[8]

In this regard, it is important to stress that, contrary to what several observers have claimed (see Abbott, 2007a; Gross, 2009; Little, 2012a; Opp, 2013a), analytical sociology does not advise starting with rational-choice theory. This association is often made by relating methodological individualism, a postulate to which analytical sociology indubitably subscribes, and rational-choice theory. However, this association is unfounded because the postulate of methodological individualism is neutral with respect to the type of theory of action chosen to portray actors' micro-level activities (see Little, 1998: 11). As stressed by Mantzavinos (2009), methodological individualism is a meta-theoretical postulate that suggests what kinds of connections may be established among levels of analysis, whereas

[8] The concept of "logic of action" has received different meanings in sociological theory (see DiMaggio, 1997: 277). Here, by "logic of action" I simply mean the basic, most fundamental mechanism that a given action-based perspective regards as the driver of actors' decision making.

theories of action contain theoretical propositions describing the actual behavior of actors. This epistemic difference implies that there is no logical connection between the quest for micro-founded explanations and the choice of a particular theory of action, in particular rational-choice theory. This is explicitly stated by Hedström and Bearman (2009b: 8) when they note that: "Although structural individualism emphasizes the importance of action-based explanations, it is essential to note that it does not imply a commitment to any specific type of motive or intentional state that is assumed to explain why individual act as they do." Second, while analytical sociology is a model-based approach, it overtly rejects the idea that simplicity should be given priority over realism with respect to the core assumptions made to describe actors' cognitive operations and activities. This induces the founders of analytical sociology explicitly and strongly to criticize the realism of rational-choice assumptions and to propose alternatives (see Hedström, 2005: 60–66; see also Boudon, 1998a; 1998b; 2003).

As a matter of fact, analytical sociology is internally heterogeneous in terms of action theory postures: "Although some analytical sociologists are rational-choice theorists, most are not" (Hedström and Bearman, 2009b: 22). Programmatically, compared to the initial insistence of Hedström (2005) on the desire–belief–opportunity scheme, analytical sociology is increasingly explicit in endorsing a pluralistic stance (see Hedström and Ylikoski, this volume). Given the variety of macro-level regularities to be explained; given the intricacy of an actor's motives; given actors' heterogeneity; and given the experimental and empirical evidence available (see below), it seems unrealistic to assume that one logic of action is likely to provide an accurate description of micro-level activities across all settings. For this reason, the logic of action on which the actor part of a generative model is based should be selected case by case and according to the empirical and experimental evidence available. Analytical sociology thus resists the tendency of sociological theory, well described by Esser (2009: 213–216), to assume that one action logic usually dominates all possible others.

Debates on rationality in sociology (see, among others, Abell, 1992; Boudon, 1998a; 1998b; 2003; Cherkaoui, 2005: Ch. 3; Ermakoff, 2010; 2013; Esser, 2009; Goldthorpe, 1998; Hedström and Stern, 2008; Kroneberg and Kalter, 2012; Lindenberg, 1992; Opp, 1999), in economics (Binmore, 2011; Gilboa, 2010; Gintis, 2009a; Sen, 2009; Smith, 2008), and in psychology (Gigerenzer, 2008) can be used to define a set of action-oriented perspectives that serve as starting points for design of the actor part of a generative model. In particular, I now briefly consider (1) rational-choice theory, (2) the theory of ordinary rationality, (3) the desire–belief–opportunity schema, (4) dual-process theories, and (5) theories of heuristic decision making. What distinguishes these perspectives, I will argue, is how they portray actors' rationality along a *continuum* whose extremes are the calculation-based rationality of neoclassical rational-choice theory and the "ecological" rationality of the "fast-and-frugal heuristic" research program.[9]

1. Rational-choice theory. When rational-choice theory is considered to model the action logic of actors, the conceptual problem that immediately arises is what "rational choice" means. The answer seems less controversial in economics than in sociology. As acknowledged by Binmore (2011: 8), the theory of revealed preferences "remains the orthodoxy in economic theory." As far as the concept of rational action is concerned, according to this framework, an actor's choice is rational when the choice is in line with the actor's preferences – where preferences are required to have a certain set of properties, among which completeness, transitivity, independence of irrelevant alternatives, temporal stability, and causal

[9] At the end of the section I will address the problem of when these different action logics are most likely to apply.

independence between feasibility and desirability are the most fundamental (see Binmore, 2011: Ch. 1; Gilboa, 2010: Chs 1–4; Gintis, 2009a: Ch. 1). In sociology, by contrast, there is no consensual definition of rationality. A common distinction is between "narrow" and "wide" versions of rational-choice theory (Opp, 1999; see also Goldthorpe, 1998), the latter substituting the strong definition of rationality as preference consistency posited by economists for a less demanding conception according to which actors' preferences and perceived constraints are both subjectively defined, actors' preferences are not limited to self-oriented motives, beliefs are not required to be correct, and utility maximization is defined on purely subjective bases.

Despite the numerousness and the authority of the scholars that propose the distinction between a narrow, economic, and a (variety of) wide, sociological rational-choice theory, I have suggested elsewhere that this distinction is built on a misrepresentation of neoclassical rational-choice theory in economics (see Manzo, 2013b). Indeed, while many applications of this theory in micro- and macro-economics are based on the restrictive assumptions usually criticized by sociologists, the rereading of the foundational, formal works by Samuelson and Von Neumann and Morgenstern by Binmore (2011: Ch. 1), Gilboa (2010: Chs 1–4), and Gintis (2009a: Ch. 1) show that the conceptual core of neoclassical rational-choice theory does not imply such restrictions.

As a consequence, I argued, if one decides to adopt rational-choice theory to build the actor part of a generative model, then one should employ the most powerful form of this approach, that is, neoclassical rational-choice theory. When this is properly understood, the conceptual core of the conception of rationality as preference consistency is perfectly able to incorporate all the theoretical elements that sociologists regard as constituting the distinctive, original contribution of sociology to rational-choice theory. In addition, because the latter drops the preference consistency assumption, it cannot rigorously define the concept of utility maximization, thus losing the powerful formal apparatus that allowed neoclassical rational-choice theory progressively to incorporate new empirical facts into the basic framework (for a more detailed discussion of this point, see Manzo, 2013b).

It would be difficult to deny that this is indeed one of the major achievements of neoclassical rational-choice theory. Over the last 20 years or so, experimental and empirical evidence generated within the field of behavioral economics and in cognitive psychology has constantly challenged the realism of neoclassical rational-choice theory as an accurate description of how real actors behave (for two overviews, see, respectively, DellaVigna, 2009, and Shafir and LeBoeuf, 2002). Economists have reacted to the increasingly long list of rationality failures by adopting what one may call a "turn-irrationality-into-rationality" strategy (see Manzo, 2013b). Instead of revising the conceptual core of the framework, economists constantly turn seeming irrationality into rationality. They do this by making actors' utility functions more complex. New parameters and/or functional forms are introduced so that more complexity at the actor level is taken into account and preference consistency is re-established. To describe this operation, others have spoken of a "repair program" (see Hertwig and Herzog, 2009: part II).

As a result, neoclassical rational-choice theory now contains very refined theoretical models whose realism in terms of the preferences and cognitive biases considered is quite high; by way of example, consider "cumulative prospect theory" (Tversky and Kahneman, 1992), Bayesian update-based models (see Zambrano, 2005), models including identity components (see Akerlof and Kranton, 2002), or fairness and equity concerns (see Fehr and Schmidt, 1999). Given the strategy followed to implement these modifications, however, the

way in which actors are portrayed remains unchanged: actors are still believed to perform more or less complex operations on more or less subjectively defined (probabilistic) distributions of payoffs under the constraints required by preference consistency.

Thus, from the point of view of analytical sociology's commitment to realism, the problem is the extent to which this representation of actors is descriptively accurate. The available experimental and empirical evidence suggests that real actors facing complex decisions often prefer not to choose (DellaVigna, 2009: 355), that they ignore fundamental components of the utility function that they are supposed to follow (Shane *et al*., 2009), and that they simply lack the capacity to formulate subjective probabilities and to update them properly (Gilboa, 2010: 56). A description of actors as more or less competent computation-makers operating over more or less biased (probabilistic) payoff distributions seems in contradiction with these observations.

2. The theory of ordinary rationality. If one has good reasons for adhering to the perspective of rational action, then a theoretical alternative to neoclassical rational-choice theory that one may consider is Boudon's theory of ordinary rationality (see Boudon, 1989; 1993; 1996; 2003). Boudon introduces two conceptual breaks with neoclassical rational-choice theory (for a more detailed analysis, see Manzo, 2012a). First, the principle of utility maximization disappears from the depiction of actors. Instead, actors are seen as reason-makers, that is, cognitive entities that spend time fabricating systems of reasons that explain to the actors what they do and what they believe. Actors do not attribute payoffs to alternatives and do not perform cost–benefit computations. The subjectively perceived coherence of the actor's system of reasons and the public defensibility of this system are the only relevant focuses of the analysis. Second, Boudon introduces the largest amount of infra-individual heterogeneity within the rational tradition. According to the theory of ordinary rationality, the range of reasons that an actor is assumed to mobilize is completely unconstrained. This is because Boudon's goal is to provide an analytical framework that makes it possible to study both the reasons that induce actors to endorse a certain set of preferences and the reasons that induce actors to select one specific option from within this set (see, for instance, Boudon, 2011; Boudon and Betton, 1999). Boudon's attempt to endogenize actors' preferences thus radically deviates from the neoclassical tradition within which rationality is confined "to the determination of means rather than ends" (Binmore, 2011: 4).

3. The DBO schema. To my understanding, the desire–belief–opportunity (DBO) schema that Hedström (2005: Ch. 3) emphasized as the backbone of analytical sociology at the level of action theory largely overlaps with Boudon's theory of ordinary rationality. The strong challenge of Hedström (2005: 60–66) against orthodox, neoclassical rational-choice theory clearly shows that DBO theory does not impose any constraint on actors' preferences, neither formal (completeness, transitivity, etc.) nor substantial (type of preferences admitted), and that it does not postulate subjective utility maximization. When Hedström (2005: 61, emphasis added) then explicitly claims that "DBO theory makes no assumption that actors act rationally, however; it only assumes that they act *reasonably* and with intention," it becomes clear that rational action is equated with reason-based action within the DBO framework.

Thus, contrary to the claims of several commentators (see Abbott, 2007a; Gross, 2009; Little, 2012a; Opp, 2013a), DBO theory, similar to Boudon's theory of ordinary rationality, exits from rational-choice theory because of the absence of the assumption of preference consistency, of utility maximization, and of the priority given to cost–benefit evaluations. As a consequence, DBO theory does not portray actors as computational devices that

perform more or less sophisticated operations over more or less (probabilistic) subjective payoff distributions, which is, I suggested, the most fundamental feature of rational-choice theory.

This does not mean that the DBO schema does not have its own problems. Similar to Boudon's theory of ordinary rationality, the extremely open conception of rationality on which the theory is based comes at a cost. As remarked by Abell (1992), the understanding of preferences and actions in terms of reasons implies that the distinction between rationality and irrationality is blurred. As a consequence, a priori, without any restriction on the kind of reasons that actors can mobilize, prediction is difficult (for a detailed analysis of this point, see Manzo, 2012a). A posteriori, the observer as well as the actor can always find good reasons to explain the actor's values and beliefs, which makes the empirical testing of the explanation problematic (see Goldthorpe, 1998). That said, as we shall see in the next section, the DBO schema of Hedström (2005: 42–59) frames actors' desires and beliefs (and opportunities) as resulting from the complex chains of dyadic interactions in which actors are embedded. This feature can help in finding regularities in the types of reasons that actors are likely to mobilize in given settings, thus increasing the capacity of the theory to formulate *ex ante facto* expectations.

Although both Boudon's theory of ordinary rationality and Hedström's DBO schema exit from the neoclassical rational-choice theory, their analytical focus is still on actors' systems of reasons. One may want to move one step further away from reason-based micro-level hypotheses by taking into account emotional and cognitive factors that impact actors' choices *over and above* their conscious acts of reason building. Hedström (2005: 41, 61) admits this theoretical possibility explicitly when he notes that "various forms of learning theories" are possible alternatives to DBO theory, and that this theory "is, for example, perfectly compatible with a selectionist trial-and-error account of action, and it recognizes the importance of various cognitive biases."

4. The dual-process approach. The so-called "dual-process" approach is useful for articulating the conscious and unconscious side of actors' actions (for a detailed overview, see Evans, 2008). There is a wide array of theories developed within cognitive and social psychology on experimental bases to account for the fact that the reflexive, conscious, highly demanding mode of reasoning required by complex decision making is highly variable across actors and, within the same actor, across situations. Dual-process theories are heterogeneous, but common to all of them is the postulate that cognition works on the basis of two fundamentally different classes of processes: one is fast, automatic, and unconscious; the other slow, effortful, and conscious. These two classes of processes are often referred to as system 1 and system 2 (see also Kahneman, 2011).

As suggested by DiMaggio (1997), the "dual-system" theoretical framework is especially interesting for sociology because it may help to integrate the micro-level mechanisms still being developed by different sociological perspectives. In particular, the automatic side of cognition is an analytical basis for closer integration between, on the one hand, meaning-centered perspectives developed within cultural sociology (see Jacobs and Spillman, 2005) and the habits-centered approach (for an overview, see Gross, 2009), and, on the other hand, the reason-based action theories at the heart of the rational-choice tradition. As testified by the "model of frame selection" initially proposed by Esser (2009) and developed by Kroneberg (this volume), this integrative view can yield precise and formalized micro-level models of human behaviors combining different mechanisms from what at first glance seem heterogeneous research traditions.

5. Heuristics-based decision making. Although psychological and sociological "dual-process" action theories do not postulate the analytical primacy of complex, conscious reflexive cognitive operations, they do not deny that these appear under certain conditions. A more radical departure from reason-based micro-level mechanisms can be found in the case of the so-called "fast-and-frugal heuristic" research program, which starts from explicit rejection of logic and probability theory as the benchmarks to use in assessing and framing actors' rationality and decision making (see Gigerenzer, 2008). As shown by the inclusion of the paper by Goldstein (2009) in *The Oxford Handbook of Analytical Sociology*, analytical sociology regards this research program as a crucial toolbox with which to formulate realistic hypotheses on actors' decision making.

The distinctive feature of this approach is that actors are assumed to make decisions and solve complex problems by creating cognitive shortcuts that prove useful in a given choice setting (in this sense, rationality is "ecologic," not intrinsic to the actor). Gigerenzer and Gaissmaier (2011: 454) define a "heuristic" as "a strategy that ignores part of the information, with the goal of making decisions more quickly, frugally, and/or accurately than more complex methods." As Gigerenzer and Gaissmaier (2011: 545) explicitly state, heuristics are conceived in this research tradition as conscious strategies, not as intuitive shortcuts acting behind the backs of actors, as is the case of dual-process theories (on this point, see also Evans, 2008: 266). This leads Gigerenzer and co-workers to develop formal models of heuristics in order to study their consequences in rigorous manner, and to assess their adaptive value compared to more traditional and sophisticated decision-making procedures.

In this regard, one of the most notable findings of Gigerenzer and co-workers is that heuristics can reproduce the behaviors of actors facing complex decisions, like managers, consumers, or physicians, better than more complex models of decision making. This is the so-called "less-is-more effect." This is an important finding because it casts doubt on the conviction that neoclassical rational-choice theory, despite its descriptive inaccuracy, should still be regarded an appropriate normative theory: that is, a theory indicating the best decision-making process that actors should follow if they want to reach optimal solutions (Gigerenzer and Brighton, 2009).

More generally, on the basis of a complex combination of observation, experimentation, and formal and computational models, Gigerenzer and co-workers have been able to accumulate a substantial amount of empirical and experimental evidence in favor of the adaptive role of a large collection of heuristics (see Gigerenzer, Hertwig, and Pachurt, 2011, and, for a shorter but dense overview, Gigerenzer and Gaissmaier, 2011). Among them, "social heuristics," namely, strategies relying on others' behavior to handle choice settings characterized by uncertainty, have received much attention, and they have been proven to be especially important for understanding the link between social interactions and actors' preferences (for an overview, see Hertwig and Herzog, 2009: 680–690).

Now, as soon as one posits that several theoretical perspectives can be mobilized to design the actor part of a generative model, the following question arises: if one does not have sufficient empirical knowledge about the micro-level mechanisms at work, what logic of action should be selected as the starting point for construction of a generative model intended to explain a given high-level (set of) regularity(ies)? This is a typical scope condition problem (on the notion of scope condition, see, among others, Foschi, 1997; Harris, 1997; Markovsky, 2010: 671–672). In this regard, the reality is that the conditions under which a given logic of action is more likely to be activated represent a problem for which at present neither

analytical sociology nor sociology more broadly have general, ready-to-use solutions (see also DiMaggio, 2002; Esser, 2009).[10]

As convincingly demonstrated by Ermakoff (2013; see also Ermakoff, 2010), the most ambitious attempts to propose a general division of labor among several action theories in terms of macro-social conditions – like Bourdieu's proposal to confine the application of rational-choice theory to times of abrupt social changes while reserving the theory of practices to ordinary, everyday social settings – have proved to be inconclusive. More precise indications come from laboratory experiments suggesting that the probability that actors' minds switch from "automatic" cognition to a more reflexive model increases: (1) the more a ready-to-use solution is absent; (2) when unexpected information or events appear; (3) when the costs incurred for a wrong decision are high; (4) when time and cognitive resources increase (see Chaiken and Trope, 1999).

As I have tried to show, however, the reflexive mode should not be equated with rationality in the sense of neoclassical rational-choice theory. For this logic of action, conditions of applicability seem even more restrictive. Gintis (2009a: 237) suggests as the application domain "choice situations where ambiguities are absent, the choice set is clearly delineated, and payoffs are unmediated, so that no deliberation is involved beyond the comparison of feasible alternatives."[11] Following Binmore (2011: 23–24 and Ch. 9), one may add to Gintis's conditions the following: the greater the actors' familiarity with probability and their willingness to learn, and the smaller the group under analysis, the higher the probability becomes that neoclassical rational-choice theory is descriptively accurate and can be fruitfully applied. Again, these are only general indications, because laboratory results show that rationality failures may also appear among subjects with high incentives, involvement, attention, and technical expertise (see Shafir and LeBoeuf, 2002: 500ff.).

1.8 Structural interdependency (P4c)

According to P4c (see Figure 1.1), the last basic element that a generative model should contain is a set of hypotheses on the structural interdependencies in which the micro-level entities postulated are likely to be embedded. We now know that this is a consequence of the structural form of methodological individualism adopted by analytical sociology and according to which the actor's action is conceived as both constrained by and productive of complex webs of institutional and relational elements.

As Hedström (2005: 43, 46, 76; see also Hedström and Swedberg, 1998b: 13) clarifies, disciplinary and substantive arguments justify analytical sociology's insistence on structural interdependence. From a disciplinary point of view, according to Weber's classic definition of the concept of "social action," the distinctiveness of sociology is that it deals with macro-level phenomena that result from subjective acts that are *mutually oriented* (for a deep analysis of Weber's concept of "orientation to others," see Swedberg, 2014). From a substantive point of view, social interdependence is crucial for understanding how actors' beliefs and desires form and change, and how actors' opportunities are shaped by others' choices. Moreover, as

[10] I would like to thank Tom Fararo who, when commenting on Manzo (2013b), drew my attention to the concept of scope condition.

[11] Note that Gintis calls these settings "routine choices," which is exactly the contrary of what one might expect according to the above-mentioned division of labor between rational-choice and practice theory proposed by Bourdieu.

Merton (1936), Boudon (1981; 1981), and Coleman (1986), among others, have suggested, interdependency among actors' actions is crucial for understanding the origin of macroscopic unintended consequences (more recently, see also Cherkaoui, 2007). In other words, as demonstrated more formally by Granovetter (1978) and Schelling (1978), social interdependence is one of the key factors that explain why there is no one-to-one relation between micro-level inputs and macro-level outputs.

In light of this literature, it is now clear that several forms of social interdependence are at work, often simultaneously (see Coleman, 1990: 20). When one comes to specify the structural part of a generative model, it is thus important to keep three analytical dimensions in mind. First, interdependence can be based on (direct or indirect) personal or tool-mediated (consider Web- or phone-based communication) interactions among individuals; but interdependence among actors can also be impersonal and mediated by social aggregates (consider market, price-mediated interdependence) (see Schelling, 1998: 33). Second, interdependence can be "parametric" when actors influence each other without being aware of this effect, or "strategic" when they intentionally modify their behavior, or try to modify their action's context, in order to respond to, or anticipate, others' behavior (see Abell, 1996; 2000). Third, all previous forms of interdependence can be induced by actors' belonging to specific institutional/organizational structures (as when one actor's mobility opportunity depends on the market position/choice of other unknown individuals), as well as by actors' embeddedness in network of personal contacts.

Among the plurality of forms that structural interdependency may assume within the space defined by these three dimensions, analytical sociology is especially (which does not mean exclusively) interested in network-based interdependencies. The rationale behind this is that, just as beliefs and desires can be considered the proximate causes of actors' actions, so local interactions can be regarded as the proximate causes of the proximate causes of actors' actions (see Hedström, 2005: 42). As DiMaggio (1997: 283) notes, from a cognitive point of view "networks are crucial environments for the activation of schemata, logics, and frames." This suggests the plausible working hypothesis that, even when actors' interdependence arises from the presence of some social aggregate, the effect of the aggregate ultimately depends on how local interactions filter it. Hedström's concepts of belief-, desire-, and opportunity-mediated social interactions – to which I have elsewhere proposed adding that of emotion-mediated interactions (see Manzo, 2011b: 303; Manzo, 2012a: 46–48) – were introduced with precisely this purpose: to orient and stimulate ever deeper analysis of the details of the mechanisms that explain how actors' beliefs, desires, and opportunity are continuously reshaped by dyadic social interactions (for a recent analysis that follows this orientation, see DiMaggio and Garip, 2012).

The way in which analytical sociology looks at network-based interdependency affords better understanding of the similarities and differences between analytical sociology and other research traditions that focus on social networks, namely relational sociology (for an overview, see Mische, 2011) and socio-physics (for an overview, see Castellano, Fortunato, and Loreto, 2009; Galam, 2004; 2008).

Compared to the former, the main difference is apparent when the strand of the literature relying on formal social networks methods is considered. Despite the heterogeneity of these methods (for an overview, see Scott and Carrington, 2011: section 1.3; see also Fuhse and Mützel, 2011), the dominant approach is still descriptive. Even some of the most advanced areas, like the simulation-based, statistical modeling of network dynamics (for two different approaches to one- and two-mode networks, see, respectively,

Snijders, 2011, and Guillaume and Latapy, 2006), do not provide details on the micro-level mechanisms of link creation and deletion (in this they are similar to quantitative studies applying multivariate statistics to non-relational data). While analytical sociology makes the effort to detail how a given (pattern of) connection(s) arises from specific actions and belief-, desire-, and opportunity-mediated influences, dynamic, statistically oriented social network analysis tends to account for the observed connections on the basis of (unexplained) network-level constraints represented by probabilistic parameters. Thus, the main difference between analytical sociology and social network analysis is the extent to which the two research traditions seek fine-grained, "substance-specific methods and models" (see Moody, 2009) of network-based interdependencies (see also the argument developed at the end of Section 1.9).

Compared to the growing field of "socio-physics" – in which, similarly to analytical sociology, patterns of local interactions among micro-level entities are also regarded as the element crucial for understanding how high-level, more or less homogeneous patterns arise (see also Easley and Kleinberg, 2010; Helbing, 2012) – analytical sociology has three main specificities. First, as testified by the formal models reviewed by Castellano, Fortunato, and Loreto (2009), analytical sociology's commitment to realism induces it to require more detailed representations of micro-level entities' cognition and behavior. Second, as a consequence, analytical sociology seeks more fine-grained descriptions of the low-level sources (in terms of entities' beliefs, desires, and opportunities) of dyadic influences among low-level entities. Finally, as acknowledged by Castellano, Fortunato, and Loreto, (2009: 593; see also Sobkowicz, 2009), socio-physics is currently characterized by "a striking imbalance between empirical evidence and theoretical modelization, in favor of the latter" (p. 593), which contrasts with analytical sociology's tension toward the empirical calibration and testing of generative models (see Section 1.10).

Notwithstanding these differences, analytical sociology, social network analysis, and socio-physics can cross-fertilize with respect to the modeling of network-based interdependency. Formal theoretical approaches focusing on network dynamics like "balance theory" (see Abell, this volume) or "e-state structuralism" (see Gabbriellini, this volume), often developed by the most mathematically oriented network analysts, as well as more statistically oriented approaches à la Snijders (see Grund, this volume), can be adapted to study the macro-level consequences of network-based interdependency. On the other hand, theoretical, simulation-based work (often developed by physicists, computer scientists, and economists) undertaken to design generic models of network topology (for an overview, see Barrat, Barthélemy, and Vespignani, 2008: Ch. 3; also see Jackson, 2008: Ch. 4 and 11) can be fruitfully exploited by analytical sociologists to define the topology of local interactions within which the hypothesized micro-level mechanisms are supposed to operate (on this point, see Fountain and Stovel, and Rolfe, this volume).

1.9 Agent-based modeling (P5)

Having posited a generative model describing the activities performed by the low-level entities, their properties, as well as the links that may exist between these activities and properties and the local network-based interactions in which the low-level entities are embedded, the next problem to be solved is that of deriving the generative model's high-level consequences.

In my opinion, this is the crucial question for a mechanism-based strategy. The "generative" understanding of causality implied by the concept of mechanism requires the demonstration that a relation between two given happenings is generated by the functioning of an underlying set of loops between structures, activities, and interactions (see Section 1.5). Thus, to be coherent with the meaning of the concept of mechanism, the connection between the mechanism postulated and the observed high-level pattern should be proved by recreating the connection itself, rather than by just verbally stating or sketching the existence of this connection. Mechanism discovery shares the rationale of reverse engineering (for an overview of this approach in the field of software development, see Eilam, 2005). The functioning of a mechanism must be designed and its consequences must be triggered, not just inferred on the basis of the mechanism's supposed signature. As provocatively stated by Epstein (2006: xii), "if you do not grow it, you do not explain it."

To solve this problem, analytical sociology's P5 proposes the translation of the theoretical "generative model" into a formal model (see Figure 1.1). In particular, the prototypical form of a "generative model" requires a kind of formalism that makes it possible to design a set of low-level entities, to detail the properties and the activities of each of them, to embed the low-level entities within patterns of local interactions, and to schedule how this system unfolds over time. Among formal models, agent-based models are types of computational models: that is, models working on the basis of algorithms which make the fine-grained design of all these elements possible (for a technical introduction, see Ferber, 1999; Wooldridge, 2009; Helbing, 2012: Ch. 2; for a more general treatment, see Epstein, 2006: Ch. 3; Gilbert, 2007).

The most general and recurrent justification for choosing agent-based computational modeling rather than equation-based mathematical models is the higher flexibility of the former (see Axtell, 2000). Any substantive mechanism for which one has a theoretical representation can be implemented and studied within the framework of agent-based modeling (see Miller and Scott, 2007: Ch. 6). As a consequence, if one values the model's realism, then agent-based computational models constitute an appealing methodological option.[12]

But what are the deep-lying causes of this flexibility? To appreciate fully why agent-based computational models can be regarded as the most powerful tools for rigorous study of the internal consistency and the high-level consequences of a generative model, it is important to conduct rapid examination of the technical foundations of an agent-based model. This can be easily done by considering the three following definitions: (1) an agent is "a computer system that is capable of independent action on behalf of its user or owner" (Wooldridge, 2009: 5); (2) "a multiagent system is one that consists of a number of agents, which interact with one another, typically by exchanging messages through some computer network infrastructure" (p. 5); (3) objects are "computational entities that encapsulate some state, are able to perform actions, or methods, on this state, and communicate by message passing" (p. 28). From a programming point of view, there is a close relation between definitions 1 and 2, on the one hand, and definition 3 on the other.

[12] Currently, pleas for agent-based models can be found virtually everywhere in the social sciences: in economics (see Axtell, 2000; Epstein, 2006; Tesfatsion and Judd, 2006; Farmer and Foley, 2009), finance (LeBaron, 2004; Mathieu, Beaufils, and Brandouy, 2005), political science (Axelrod, 1997; Cederman, 2005), geography (O'Sullivan, 2008), criminology (Birks, Townsley, and Stewart, 2012), epidemiology (see Auchincloss and Roux, 2008), social psychology (Smith and Conrey, 2007), demography (see Billari and Prskawetz, 2003), and sociology (see Macy and Willer, 2002; Macy and Flache, 2009; Sawyer, 2003).

In fact, an agent-based model is made up of "objects." According to the bundle of properties and rules that one programs for a given class of objects, the latter can be used to design the behavior and interactions of a set of particles, molecules, cells, beliefs, actors, groups (of particles, molecules, etc.), organizations, or whatever else on which one may have a precise theoretical understanding and representation. Thus, despite their name, agent-based models are not at all limited to representing "individuals." At the deepest level, the flexibility of these computational methods arises from the conceptual emptiness of the fundamental units ("objects") on which an agent-based model is built, and from the power of "object-oriented programming" in the creation and manipulation of computational objects (on this point, see Hummon and Fararo, 1995).[13]

Conceiving agent-based models in terms of their fundamental components (i.e., "objects") also affords better understanding of the interesting parallel that exists between what analytical sociology aims to model (i.e., mechanisms) and the method (i.e., agent-based models) it proposes for developing models of mechanisms (i.e., generative models). We have seen earlier that, in its most general form, a mechanism consists of a set of interdependent entities, their properties, and their activities. We now know that an agent-based model amounts to a collection of communicating objects, their attributes, and their procedures (functions or methods) which define the behavior of the objects. Thus, there is a structural homology between the "entities/entities' properties/entities' activities" triad composing the basic structure of real-life mechanisms, and, on the other hand, the "objects/objects' attributes/objects' procedures" triad composing the backbone of an agent-based model (compare the two dashed boxes in Figure 1.1). As a consequence, the agent-based computational model can be regarded as an artificial computing mechanism whose specific content is designed to mimic the detailed functioning of the real-world mechanism (on the concept of "computing mechanism," see Piccinini, 2007).

Moving from the static (i.e., the mechanism design part) to the dynamic side of an agent-based computational model (i.e., the simulation of the artificial mechanisms posited), it becomes apparent that this method is a direct implementation of the concept of "generative causality." Simulating an agent-based model means updating the attributes attached to the objects of which it is made up, iterating the rules that define the objects, and letting the objects communicate, thus influencing each other over (the simulated) time. Hence when one simulates an agent-based model, one is activating *in silico* the process that the artificial mechanism potentially contains. What this process generates is exactly what analytical sociology seeks: evidence that a given representation of a given set of interconnected entities/properties/activities, that is, a "generative model," is able to generate a given set of high-level associations. Thus, within an agent-based model, the "generativity" requirement is implemented by means of what has been called "algorithmic causality": that is, the unfolding over time of a well-specified set of rules and operational instructions detailing how a set of clear

[13] One possible objection to the connection that I am establishing between agent-based modeling and what I regard as its fundamental components, that is, "objects," is that one does not need object-oriented programming to design an agent-based model. In fact, procedural and functional programming languages can also be used to code and simulate agent-based models (see Nikolai and Madey, 2009). The fact is that the objected-oriented approach makes the coding of an agent-based model easier and more flexible. Moreover, conceptually, it provides a framework that gives clearer and more immediate visibility to the specificity of agent-based modeling. Thus, the greater power of object-oriented programming justifies the claim that one gets the best out of agent-based modeling if one conceives and designs it in terms of computational "objects."

specified entities (at the different levels of analysis) is able to lead the system under scrutiny from state A to state B (see Doreian, 1999: 98–99).

Once the deep foundations of agent-based computational modeling are understood, it is easier to discuss more specific aspects of this approach that explain why analytical sociology is right to regard this method as a powerful means to study generative models. I briefly focus here on the following aspects: (1) action theory; (2) social heterogeneity; (3) social interaction; (4) infra- and supra-individual entities.

Since analytical sociology systematically seeks micro-founded explanations, the first point to be addressed concerns the relation between agent-based model and action theory. In this regard, it is essential to understand that agent-based modeling is entirely agnostic about the logic of action by which agents are driven. This is simply a consequence of the above-noted conceptual emptiness of the "object-oriented" methodology. Artificial agents can be programmed as more or less sophisticated rational-choice theorists (see Shoham and Leyton-Brown, 2009), and agent-based models are often used in economics to solve game-theoretic models that cannot be solved analytically (see for instance Zambrano, 2004). But this connection between neoclassical rational-choice theory and agent-based modeling is not necessary at all. As the complex and heterogeneous research field of "cognitive agents" shows, artificial agents can be programmed as intentional agents performing more or less complex logical operations that are variously different from utility maximization (see Wooldridge, 2000). But, as noted by many authors (see for instance Miller and Page, 2004: 10), artificial agents can also be designed to behave according to simple rules of thumb, that is, "heuristics." Interestingly, when evolutionary games portray actors as following simple, local imitation rules, it is precisely agent-based modeling that is used to simulate the dynamic of the model (see Alexander, 2007: 38–42; Gintis, 2009b: 72–73).

Social heterogeneity is a second element that agent-based modeling makes it possible to represent without constraints. "Object-oriented" programming enables the straightforward introduction of at least four types of heterogeneity: (1) objects belonging to different classes have different attributes; (2) within a given class, objects obtain different values on given attributes; (3) objects can be heterogeneous in terms of activities, tasks, or the behavior rules by which they are driven; and (4) objects can be activated according to different temporal schedules.

This is a fundamental point. As Gallegati and Kirman (1999) pointed out in their critique of neoclassical economics, agent-based computational modeling is a robust formal tool that enables us to go beyond the metaphor of the "representative agent." In reality, actors are heterogeneous in terms of beliefs, desires, and logics of action. Heterogeneity matters in explaining macroscopic outcomes because heterogeneity spreads across social networks. Agent-based modeling allows us to represent heterogeneity and study its macroscopic effects.

Given analytical sociology's focus on structural interdependency, social interactions are a third element that makes agent-based modeling especially attractive for analytical sociologists. Since computational "objects" are not limited to any specific substantive content and, as stressed by Woodbridge's above-mentioned definition, objects communicate with each other (at the deep level of a computer's memory address system), "objects" can be used to design both space- and network-based local interactions (see Rolfe, this volume). In the former case, what matters is the agent's location in a physical space, so that the agent's neighbors are defined on the basis of more of less complex spatial proximity rules. By contrast, in the latter case, the physical location of agents is not the primary concern, so that the agent's neighbors are determined by the overall topology of connections assumed to characterize the population

under scrutiny. Combinations of space- and network-based local interactions can also be implemented.[14] What matters here is that, no matter what specific structure of local interactions is theoretically imagined, an agent-based computational model makes it possible to represent this structure, and mechanisms can be designed to represent how agents' beliefs, desires, and opportunities are locally influenced – directly by the behavior of the agent's local neighbors, and indirectly by the network's topology (see Fountain and Stovel, this volume).

Last but not least, given the complex form of methodological individualism discussed in Section 1.6, analytical sociologists should be sensitive to agent-based modeling's capacity to handle entities at different levels of analysis. Once again, because the fundamental units on which agent-based models are built (i.e., "objects") are conceptually empty, agents are not limited to representing real-world actors. As testified by advanced agent-based "architectures" (see for instance Ferber, Gutknecht, and Michel, 2004; Ferber, Michel, and Baez, 2005), classes of objects representing different types of entities at different levels of analysis can be designed and can co-exist and communicate within the same model. Thus, objects can, for instance, be used to represent organizations, and the communication among objects can be used to represent forms of downward causation from a given organization to a given actor (actors being represented by another class of "objects"); this is so even if the actor concerned does not belong to the organization or does not participate in the production of the organization's current state. One can also implement forms of macro-to-macro or meso-to-meso correlations by letting objects representing entities at one given level of analysis influence each other without the intervention of objects representing entities at lower levels of analysis.

Needless to say, "objects" themselves are all located at the same level of analysis, so to speak. They only (physically) exist at a computer's memory level. In this sense, the limitation of computation pointed out by Boschetti (2011) is real. However, this limitation does not imply that it is impossible to use an agent-based computational model to represent connections among different levels of analysis (for this objection, see Hédoin, 2012). The specific way in which an "object" is programmed and the specific type of relations that the programmer establishes among different classes of "objects" incontestably allow representation of any form of connections and exchanges among entities located at different levels of analysis.[15]

Thus, agent-based modeling represents a flexible virtual laboratory enabling the implementation of generative models as complex as one wants. Historically, this is a great methodological opportunity. Since agent-based models are based on object-based algorithms and are solved by simulation, mathematical tractability is no longer a constraint for the kind of mechanisms that one wants to represent. This means that some of the assumptions usually made to keep computation simple and make the model analytically solvable can be dropped. Agent-based modeling breaks down the trade-off between simplicity, realism, and formal

[14] It is important to note that the distinction between space- and network-based interactions is analytical. From a formal point of view, it is possible to translate one form into the other (see Alexander, 2007: 42–44).

[15] Consider the example that I have discussed in note 7 in terms of class of "objects." One class of objects may represent "formal rules" whereas another class of objects may designate "actors." One may then program a set of instructions defining how the objects of the class "formal rules" evolve and influence each other over time. This dynamic among objects belonging to the class "formal rules" may or may not be coupled with a dynamic involving the objects that belong to the class "actors." It is clear that both classes of "objects" only exist as electric states at one level of analysis (the computer's memory), but the way in which we characterize, combine, and manipulate these states allows us to represent multi-level dynamics.

tractability. If one agrees to move from calculus to (perhaps less elegant) algorithmic computation, then formal models are no longer trapped in the dilemma of being either simple, unrealistic but tractable, or more complex and realistic but less tractable. This is why some have argued that agent-based modeling is the right mathematics for social sciences (see Borrill and Tesfatsion, 2010).

In the previous sections, the claim has been made that multivariate statistics has limitations for the study of generative models. The above discussion of agent-based modeling's foundations should help make the claim more concrete. The crucial point is that multivariate statistics cannot achieve the flexibility of agent-based computational models for mechanism design. What "object" manipulation enables one to accomplish is simply beyond the reach of "variable" manipulation.[16]

This seems especially evident with respect to mechanisms that imply actors' embeddedness in network-based interdependencies. Empirical quantification of the net effect of neighborhood- and network-based social influences on individual outcomes has proved extremely difficult (see, respectively, Mouw, 2006; Sobel, 2006; Sampson, Morenoff, and Gannon-Rowley, 2002; Shalizi and Thomas, 2011; and VanderWeele, 2011). As demonstrated by Manski (1993a; 1993b)), if two actors are (spatially or relationally) related and end up with a similar outcome, "ecological," "contextual," and "correlated" effects are difficult to distinguish empirically from truly "endogenous" effects on the basis of non-experimental observational data (for an overview, see Durlauf and Ioannides, 2010). From a statistical point of view, this implies that the problem of unmeasured heterogeneity tends to produce biased estimations (Harding *et al.*, 2011). In addition, the "reflection problem" complicates interpretation of the direction of the causality.

While agent-based modeling cannot help solve these estimation and identification problems on empirical grounds, at the theoretical level, it offers a unique opportunity for rigorous study of space- and/or network-based interdependencies. First of all, there is no unobserved heterogeneity within an agent-based model. By construction, since the modeler defines them, all group- and individual-level variables defining agents' attributes are perfectly known. Similarly, because agents' spatial and network locations are defined by the modeler, the way in which agents are linked together and the composition of their local neighborhood are also completely transparent. "Ecological," "contextual," and "correlated" effects are thus completely controlled for. Moreover, they can be easily separated from "endogenous" effects. By means of appropriate procedures to control for model stochasticity, it is in fact possible to rerun exactly the same simulation with and without the network-based social influence mechanisms. The net effect of being in contact with a given set of agents over and above the effect associated with the distribution of individual-level characteristics can thus be isolated. Finally, the "reflection" problem can be handled efficiently. As we have seen, within an agent-based model, the sequence of events – the model scheduling – is defined by the modeler so that, although sometimes complicated, it is possible to establish what causes what.

Thus, agent-based computational modeling is a good candidate to design directly, and trigger the effects of, network-related mechanisms rather than "to infer interaction processes from the observation of their outcomes" (see Manski, 2000: 132).[17]

[16] To some extent one may ask if claiming that "statistical technique of causal modeling in general is an appropriate instrument to test mechanism-based explanations" (see Opp, 2007: 121) does not simply misunderstand what statistics is.

[17] I have attempted to provide a concrete example of this argument in Manzo (2013b).

1.10 Back to data (P6 and P7)

In the previous section I argued that agent-based modeling is the most coherent methodological framework with which to build and study models of mechanisms because the internal deep structure and functioning of an agent-based computational model make it possible to design artificial mechanisms as detailed as one wishes and to trigger the high-level consequences associated with these artificial mechanisms. On its own, however, agent-based modeling cannot provide the proof that the mechanism(s) represented by the generative model under scrutiny is(are) the mechanism(s) underlying the high-level regularities to be explained.

As stated by Macy and Sato (2008), "it is empirical research, not an agent-based model, that bears the burden of proof. The computational model can generate hypotheses for empirical testing, but it cannot 'bear the burden of proof'." As noted by Epstein (2006: 8), agent-based modeling can only assure "generative sufficiency" – "agent-based computational models provide demonstrations that a given micro-specification is in fact sufficient to generate a macrostructure of interest."[18] The agent-based model, however, cannot on its own prove descriptive accuracy between the artificial and the real-world micro level, as well as, on the other hand, between the simulated macrostructure(s) and the real-world high-level regularities to be explained.

In order to assess the extent to which the generative model implemented in the agent-based model approximates the real mechanism(s) at work, the kind of analytical sociology depicted in Figure 1.1 suggests submitting the agent-based model to two different empirical tests. On the one hand, P6 advises comparing the high-level numerical patterns generated by the agent-based model to the empirical high-level regularities to be explained. On the other hand, P7 suggests an even more demanding test, which consists of an attempt to ground directly the main agent-based model's component on empirical data.

It is important to understand why the high-level empirical validation required by P6 should precede the low-level empirical calibration demanded by P7. Exploring the agent-based model's parameter space (sensitivity analysis) and systematically modifying some secondary details of the model's specification, like functional forms (robustness analysis), are operations crucial for assessing the extent to which the generative model under scrutiny is able to generate the outcome of interest (see Railsback and Grimm, 2012: Ch. 23). In the absence of this analysis, one risks seeking empirical validation at the micro and network level for a generative model that is unable to generate (with regularity and under realistic combinations of parameters' inputs) the high-level patterns/trends for which it has been devised.[19]

[18] Epstein's use of the word "demonstration" warrants comment. An agent-based model provides a "demonstration" in that, once the numerical/logical inputs for the model's parameters are set up, the execution of the program coding the generative model deduces the simulated outcome from the inputs, given the details of the algorithms designed to implement the model. As noted by Epstein, "every realization of an agent-based model is a strict deduction" (p. 56). Thus, an agent-based model provides a "constructive proof" – the outcome is created rather than inferred – that a given mechanism model is able to generate a given pattern (on the concept of "constructive proofs," see Borrill and Tesfatsion, 2010).

[19] As a by-product, systematic sensitivity and robustness analyses increase the probability of discovering errors in the computer code. This is an unfortunate possibility that should be kept constantly in mind. Although critics of simulation methods use this problem to disqualify the approach, encouraging signs of progress exist. First, there is a constant tendency toward procedure standardization (Galán *et al*., 2009; Grimm *et al*., 2010; Richiardi *et al*., 2006; Sargent 2012). Second, resources are now available to publish computer code and make it available (see Janssen *et al*., 2008). Third, replication studies are increasingly encouraged (see Wilensky and Rand, 2007). That said, as Joppa *et al.* (2013) show in their paper, it would be a mistake (though perhaps psychologically reassuring) to think that the problem of coding error is exclusive to agent-based modeling.

Thus, what one may call the "outcome-range-oriented" use of agent-based modeling is valuable on its own (see Centola, Macy, and Willer, 2005; Macy and Sato, 2002; Manzo, 2011b). It teaches us the (possibly entire) set of high-level consequences that the generative model under scrutiny is able to generate, as well as the area of this outcome space within which the high-level empirical pattern(s) of interest is(are) most likely to fall. In addition, patiently exploring the range of simulated high-level outcomes associated with the generative model under scrutiny also aids understanding of the simulated process through which the mechanisms programmed lead to the outcome(s). Indeed, while these mechanisms are completely transparent to the modeler, the process that they trigger is not necessarily equally transparent. Differently from the real world, however, this process can be inspected within the artificial settings of an agent-based model and progressively understood. For this task, mathematics proves to be a powerful complement to computation (see Izquierdo *et al*., 2013).

Once one is sufficiently confident that the computational translation of the generative model postulated is able to generate high-level patterns/trends that fit the empirical high-level patterns/trends of interest – a task for which technical solutions are still under debate (see Fagiolo, Windrum and Moneta, 2007; Thorngate and Edmonds, 2013) – one enters analytical sociology's principle 7, which proposes turning the agent-based model at hand into an empirically calibrated, agent-based model (see Hedström, 2005: Ch. 6). The idea here is not simply to look for empirical justifications of the micro- and network-related assumptions whose generative sufficiency has been previously proved. The requirement is to inject the most appropriate data into the agent-based model empirically so as to constrain its functioning as much as possible.

According to data availability and to the specific generative model under scrutiny, different types of empirical information can be exploited. First, the attributes of the agents, be these individual or collective, can be set up on the basis of the exact values or the qualitative properties of the empirical distributions of these attributes (see Brown and Robinson, 2006; Bruch and Mare, 2006). Second, the functional forms relating (some of) these attributes can be estimated empirically (see Hedström, 2005: Ch. 6). Third, the behavioral rules according to which agents behave can be drawn from qualitative observation (see Moss and Edmonds, 2005; Moss, 2008) and/or experimental settings (see Duffy, 2006; Fischbacher and Gächter, 2010). Fourth, network-related attributes like average degree, clustering, or the probability of tie creation/deletion can be imported from analyses of real- or Web-based social networks (see Rolfe, this volume). Finally, agents' locations and space-based patterns of local interactions can be indexed on real-world geo-referenced data (see Crooks and Castle, 2011; Girardin and Cederman, 2007).

The goal of these operations of empirical calibration is to increase our confidence that the generative model under scrutiny is the most empirically plausible explanatory candidate. Because a given simulated outcome can often be generated under different value combinations for the core parameters of the model and under sometimes markedly different representations of a given mechanism, if one knows the real-world values of a given parameter, a given attribute distribution, a given behavior rule, or a given network topology, then one is restricting the set of alternative representations of a given mechanism that may lead from the same inputs to the researched output. As a consequence, if the empirically grounded version of the agent-based computational model is still able to generate the high-level empirical regularity at hand, then one's conviction that the generative model under scrutiny is grasping the real-world mechanism may legitimately increase.

That the notion of empirically calibrated, agent-based models is not related to any particular types of data creates opportunities for fruitful collaboration among analytical sociologists with different understandings of the analytical sociology research program, as well as between analytical sociologists and scholars with different research agendas. Those who believe in the power of agent-based modeling to devise models of mechanisms, but, at the same time, do not believe that agent-based modeling can provide *on its own* the ultimate proof (if any) that the mechanism guessed is the real mechanism at work, should be constantly receptive to the results of quantitative, qualitative, and experimental research in order to acquire empirical information to be injected into the agent-based models on which they are working. On the other hand, scholars more involved in quantitative, qualitative, or experimental research may benefit from the agent-based methodology partly by understanding better where the (neat) complex correlations that they observe come from, and partly by learning more about the high-level consequences of these correlations once they have been introduced into a larger, organized, and dynamic system implemented and studied by means of agent-based simulations.[20]

About 10 years ago, Morgan (2005: 26) made the following assessment of the book by Hedström and Swedberg (1998a) with respect to methodology: "Sorensen and others got it only partly right. Without a doubt, they correctly identified a major problem with quantitatively oriented sociology. But, they did not offer a sufficiently complete remedy." While all problems are far from being fixed, it seems to me that the combination of P5–P7 discussed in the last two sections defines a clear and organized strategy for the empirical testing of models of mechanisms. Far from simply, and naively, relying exclusively on agent-based computational modeling (for this objection, see Abbott, 2007b: 1; Lucchini, 2007: 236–240, Lucchini, 2008: 9–12, Sawyer, 2007: 260), this strategy establishes a complex interface among multivariate statistics, computational methods, mathematics, and experiments in which each method is mobilized to accomplish specific tasks. I will explain in the general conclusion to the book why, in my opinion, this proposal should not be regarded as a new expression of what Elster (2009a) called "excessive ambition."

1.11 Concluding remarks

This essay started with the idea that analytical sociology is a complex and heterogeneous intellectual movement whose content and boundaries are still under development and debate. Scholars who feel themselves close to analytical sociology's spirit have different points of

[20] That said, one should not underestimate the difficulties of the empirical calibration strategy. First, it should be noted that the requirement of empirical calibration may induce selection of high-level outcomes and low-level hypotheses as a function of data availability. A protection against this risk is valuing the use of agent-based modeling as a tool to assess the internal coherence of generative models. Second, it should be borne in mind that a full calibration of an agent-based model, and thus a full empirical test of a mechanism model, is virtually impossible because the detailed information required to ground an agent-based model empirically is often lacking. In fact, this is precisely the main reason for wanting to simulate the mechanism. In the ideal, extreme situation in which all the details were known (if we had the omniscience that some attribute to God), we would not need to simulate. In this case, we would have an immediate, complete understanding of the mechanism and of the process it triggers. Description and explanation would conflate. Third, empirically calibrating an agent-based model raises the complex technical questions of how the empirical information injected into the model at the outset is updated during the simulation and of the extent to which the realism of this information is constant over the simulated time. These are difficult questions for which precise answers have not yet been provided.

view in regard to the scope of analytical sociology, the understanding of the concept of mechanism, the interpretation of methodological individualism, the kind of theory of action to be adopted, and the potentialities and limitations of multivariate statistics and of formal modeling. This state of affairs suggests that analytical sociology is at an advanced stage of maturation. Indeed, as classic analyses of disciplinary specialties formation show (see Mullins, 1972), the co-existence of several subgroups sharing a similar intellectual focus and research style is one of the signs that a specialty has in fact crystallized.

I have suggested that this heterogeneity explains both the growing attention to analytical sociology and the strong criticisms that it has received. From outside, the multi-faceted nature of analytical sociology makes it appealing for scholars with different theoretical and methodological interests; at the same time, the heterogeneity of analytical sociology dilutes the visibility of its core, thus giving critics the occasion to attack the approach because of its supposed lack of distinctiveness.

The bulk of this essay has then attempted to clarify one specific understanding of analytical sociology as a set of seven logically connected, thus interdependent, principles that generate a specific type of model building and testing research strategy. I have suggested that this set of principles should be regarded as a research program in the sense of Lakatos (1972: 132), that is, as a set of "methodological rules: some tell us what paths of research to avoid (negative heuristics), and others what paths to pursue (positive heuristics)." I believe that the set of principles proposed draws the most coherent implications from a certain understanding of what a mechanism-based explanation is. As soon as one accepts that the concept of mechanism epistemically relies on a reverse engineering perspective, according to which a given observed connection is explained only when one produces the proof that the connection at hand can be recreated, physically or numerically, on the basis of a clearly specified set of rules, then the set of principles discussed is, I submit, the most powerful one with which to fulfill the requirements of this conception of scientific explanation. These principles, I have argued, are likely to lead analytical sociology toward an empirically oriented, experimentally and computationally based, macro-sociology with clearly explicated and empirically grounded dynamic micro- and network-level foundations. As I will argue in the general conclusion to the book, this conception seems the one most likely among possible understandings of analytical sociology to stimulate the largest set of "problem shifts" in sociology in the long run.

In my view, the set of principles discussed in the previous pages also increases the probability that the distinctiveness of analytical sociology within contemporary sociology will be appreciated. The critics of analytical sociology tend to focus on a subset of the principles summarized in Figure 1.1. Usually, they discuss at length some aspects of principles 2, 3, and 4, namely methodological individualism and action theory, but they address at best only rapid remarks to principles 5, 6, and 7. They take some or other element and argue that it characterizes other sociological perspectives as well. In this manner, however, the coherence of the whole as a complex model-building and testing research strategy is destroyed and the specificity of analytical sociology is lost.

By contrast, once the interdependence among the elements summarized in Figure 1.1 is taken into account, it is easier to see that the overlap between analytical sociology and other perspectives within and outside sociology is only partial. The quest for conceptual and stylistic clarity (P1) is without doubt shared by a large proportion of sociologists. This requirement, however, does not necessarily induce the majority of those sociologists to consider formal modeling (P5) as the most coherent way to fulfill the clarity requirement.

Several perspectives value good empirical description (P2), but few of them regard formal modeling (P5) as the most powerful tool with which to complement qualitative, thick descriptions and quantitative, correlational analysis. An explicit focus on mechanism-based explanations (P3) is far from being exclusive to analytical sociology. However, one less frequently finds mechanism understandings which combine micro-foundations (P4a) with relational embeddedness (P4c), and, on the other hand, propose the modeling and study of mechanisms by means of agent-based computational models (P5). Action-oriented perspectives (implied by P4b) are widespread in sociology, but few of them pay attention to the heterogeneity of action logics (within and across actors) (P4b) and, at the same time, to the potentialities of agent-based computational modeling for studying the macroscopic consequences of this heterogeneity at the micro level (P6). Many approaches stress the relational bases of social life and aim to study structural interdependency (P4c). However, it is less easy to find perspectives that combine this focus, on the one hand, with a micro-founded, mechanism-oriented perspective (P3–P4a), leading to an examination of how connections emerge and how they affect actors' desires, beliefs, emotions, and opportunities (P4c), and, on the other hand, with agent-based computational modeling (P5). Formal modeling (implied by P5) is no doubt at the core of various research traditions within and outside sociology, but it is not necessarily associated with an explicit mechanism-based thinking (P3). It is not necessarily thought to be compatible with computational modeling; and the empirical testing of the model's high-level consequences (P6), as well as of its micro- and relational-level bases (P7), is not necessarily regarded as a task of primary importance.

One fact suggests that, despite these partial overlaps, the research program of analytical sociology discussed in this essay represents an original and distinctive proposal in sociology. This fact is the scarcity of sociological analyses that combine *at the same time* all the principles summarized in Figure 1.1. How often, indeed, does one see articles published in sociological journals in which, *at the same time*, (1) advanced statistical techniques and/or rigorous qualitative research protocols are used specifically to figure out the explananda, (2) formal models are devised to formulate hypotheses about the mechanisms responsible for the observed (robust) correlations, (3) simulation is used to go from the postulated mechanisms back to the patterns to be explained, and (4) survey, experimental, and/or ethnographic observations are in turn used to discard alternative specifications of the substantive content of the formal model?

It is certainly possible to point to an array of empirical studies that have started to make efforts to approximate the entire set of principles summarized in Figure 1.1. Macro-patterns and diffusion processes related to sexual networks (Bearman, Moody, and Stovel, 2004), to unemployment (Hedström, 2005: Ch. 6), to residential segregation (Bruch and Mare, 2006), to unpopular norms (Willer, Kuwabara, and Macy, 2009), to new technologies (DiMaggio and Garip, 2011), to fertility decisions (Gonzalez-Bailon and Murphy, 2013), or to educational inequalities (Manzo, 2013a), for instance, have recently been investigated by means of a complex mix of statistical methods, social network analysis, agent-based simulations, and experiments, the aim being to uncover the reason- and network-based mechanisms that have generated these patterns.

These multi-method empirical analyses are still infrequent, however. This signals that the analytical sociology research program is not particularly common within contemporary sociology; that this research program has a clear specificity; and that there is scope for its further development.

1.12 How to read this book

Analytical Sociology: Action and Networks modestly aims to contribute to this development of analytical sociology. By discussing its principles and multiplying the social phenomena brought under scrutiny, the essays collected in the book constitute important variations on the seven principles discussed in this chapter and summarized in Figure 1.1. Each chapter provides theoretical and/or methodological resources and solutions to develop further and to implement specific elements of Figure 1.1. In selecting the contributors, my aim was not to oblige them to adhere to the variant of analytical sociology that I have defended in the previous pages. Nor was I interested in knowing whether they accepted or rejected the label "analytical sociology." My intent was instead to collect resources for the further development of a specific understanding of analytical sociology. Setting up a research program is a collective enterprise, and we know that distributed heterogeneity helps us find better solutions and enriches our thinking (Page, 2007). This is the spirit behind *Analytical Sociology: Action and Networks*.

Accordingly, I will not summarize here the content of each chapter. This is done by the editor's chapter outline that precedes each contribution. In the spirit of knowledge accumulation, these chapter outlines also serve the purpose of connecting the chapter with previous programmatic manifestos of analytical sociology, as well as with other sociological approaches. Here I merely suggest some theoretical and methodological themes that cross-cut the collected essays and show how these essays contribute to further discussion of the set of principles discussed in this introductory essay. This should also help the reader to design his/her own path through the rest of the book.

While the complex interplay between actors' actions and actors' social and structural embeddedness is the common feature of all the contributions, the book's first part contains those which focus more explicitly on the action side. Thus, Hedström and Ylikoski (Ch. 2), Wikström (Ch. 3), Kroneberg (Ch. 4), and, although less overtly, Franzosi (Ch. 5), Mitschele (Ch. 6), Barrera (Ch. 7), and Grossman and Baldassarri (Ch. 8) consider the realism of micro-founded explanations; and, in different ways, they all contribute to assessing the limitations of neoclassical and broader versions of rational-choice theory. By contrast, the book's second part consists of chapters whose primary focus is on network-based interdependency. Some of these chapters, like the one written by Rolfe (Ch. 9), address the important issue of (realistic) network topology for agent-based modeling, whereas others, like those by Abell (Ch. 11), Grund (Ch. 12), and Gabbriellini (Ch. 13), deal with network formation and dissolution; yet others, those by Gonzales-Bailon and co-authors (Ch. 10), Fountain and Stovel (Ch. 14), and Takacs and co-authors (Ch. 15), study the effect of actor network embeddedness on actors' opportunities and beliefs. These chapters build on statistical, mathematical, and simulation-based methods, often combining them. And they show in concrete how social network analysis and analytical sociology's mechanism-oriented thinking can complement and enrich each other.

Some chapters contribute to our thinking about how standard survey data can be complemented by other data and/or "twisted" when the understanding of social mechanisms is at stake. In this regard, Wikström's contribution (Ch. 3) provides insights important for creative data collection procedures, and the chapter by Gonzalez-Bailon and co-authors (Ch. 10) devises original procedures with which to infer micro-level elements from aggregate data. Other essays, like those by Barrera (Ch. 7), Grossman and Baldassarri (Ch. 8), and Takacs and co-authors (Ch. 15), are based on experiments and address the complex issue of the extent to which social mechanisms can be grasped by this methodology, partly combined in some cases with multivariate statistics. Finally, Chapter 16 by Kovacs assesses the extent to which the

description of meso-level entities and dynamics involving organizations can be related to some of analytical sociology's principles.

With the exception of Hedström and Ylikoski (Ch. 2), all the authors address the above-mentioned theoretical and methodological points on the basis of substantive analyses of specific social phenomena. With the exception of Barrera (Ch. 7), Rolfe (Ch. 9), and Abell (Ch. 11), all contributors mobilize (or produce) original empirical data. In particular, Franzosi's and Mitschele's contributions (Chs 5 and 6) exploit historical data, thus opening analytical sociology to, and testing its relevance for, historical sociology. On the other hand, Gonzales-Bailon and co-authors (Ch. 10), Gabbriellini (Ch. 13), and Kovacs (Ch. 16) build on Web-based or online communication data, thereby connecting analytical sociology with the newest forms of data exploitable to study social mechanisms.

Hence, as the book's organization in terms of substantive topics signals, *Analytical Sociology: Action and Networks* intends to contribute to the further development of analytical sociology by putting its principles into practice, and by using problems and results that arise from concrete pieces of research to challenge and refine those principles.

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Coda

Problem shift in sociology: Mechanisms, generic instruments, and fractals

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Analytical Sociology: Actions and Networks is not the first book on analytical sociology – and it is likely not to be the last. It has the advantage of a latecomer: it benefits from the knowledge of, and the debates on, analytical sociology over the past 10 years or so. Compared to its predecessors, *Analytical Sociology: Actions and Networks* has thus been in a position to see, and explicitly to acknowledge, the internal heterogeneity of this perspective. It has been able take the risk of putting forward a specific conception of analytical sociology, and of locating it within the current diversity of analytical sociology understandings. It has been able to focus on two analytical pillars of the approach, that is, "actions" and "networks," and to stimulate methodologically rich, substantive analyses of specific micro-, meso-, and macro-level regularities. Several chapters in the book open analytical sociology to, and dialog with, different theoretical traditions in both the fields of action theory and network analysis. Some of the chapters have even approximated the full circular research path outlined in my introductory essay: moving from the empirical description of aggregate data to the formulation of a generative model, with its translation into a computational model, and then finally returning to the original data.

Hence *Analytical Sociology: Actions and Networks* proves that analytical sociology is acquiring scientific maturity and it raises the crucial question of the approach's identity. The introductory essay proposed a specific answer to this question by suggesting that analytical

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sociology now consists of an empirically oriented, experimentally and computationally based, macro-sociology with clearly explicated and empirically grounded dynamic micro- and network-level foundations. This specific understanding of analytical sociology stems from the close connection that can be established between the concept of mechanism and that of "computational" object. As soon as one posits that explanation through the modeling of social mechanisms amounts to an operation of reverse engineering – whereby an observation can only be explained if it can be recreated – one shifts naturally from the concept of mechanism to that of "computational" object, the latter being the basic methodological unit of the most flexible formal tool, that is, agent-based modeling, with which to recreate *in silico* the connection postulated between a given set of low-level mechanisms and their high-level consequences. According to this understanding of analytical sociology, empirical information of every sort should then be used to convince the audience that the artificial mechanisms designed to recreate the low–high-level connections *in silico* do indeed mimic the real-world mechanisms.

In this regard, *Analytical Sociology: Actions and Networks* is without doubt heterogeneous. The contributors to the book do not uniformly apply this view of analytical sociology. In fact, the contributions that attempt to solve specific empirical puzzles by mobilizing specific datasets design five different *modi operandi* to study social mechanisms in practice.

Some authors first describe the empirical data. They then discursively outline the pattern of the interplay among structures, actions, and networks that may have generated the empirical observations. Finally, they look for the empirical evidence available that may support this or that element of the given verbal description of the mechanism(s) at work. Other authors start with a pre-established idea of the mechanisms at work. They then verbally formulate expectations as to what should be observed empirically. Finally, they use multivariate statistics to verify the existence of robust correlations reflecting their theoretical expectations. Other authors also verbally sketch both the mechanism and the correlation that one should expect to find if the postulated mechanism(s) were at work, but they use laboratory or in-field experiments to prove that these correlations hold empirically. Interestingly, multivariate statistics are also used by these authors in order to convince the reader that the correlations experimentally observed indeed arise from the verbally postulated mechanism(s). Still other authors use mathematics to express the hypotheses on the underlying mechanism(s). They then study the formal model analytically, or by means of simulation, in order to derive theoretical correlations. Finally, they use multivariate statistics to verify whether these correlations exist in specific datasets. Yet other authors program virtual societies detailing stylized actors' actions and interactions. They then generate bottom-up simulated observations to be compared to real-world observations and analyze them by means of statistical tools as if they were real datasets.

Readers and commentators will probably complain about this heterogeneity. Even worse – given that the last *modus operandi* is the only one that accords with the understanding of analytical sociology discussed in my introductory essay – reviewers will probably criticize the partial mismatch between the book's introductory essay and the rest of its content.

But, I submit, this is precisely the strength of *Analytical Sociology: Actions and Networks*. More clearly and overtly than before, it proposes two basic ways to study social mechanisms: on the one hand, the *modus operandi* that requires the direct design of an artificial mechanism in order manually to trigger and recreate its consequences; and, on the other, the approach that consists of inferring a mechanism from observation of its effects. The introductory chapter opts for the former approach and proposes it as a benchmark against which to assess the

variants of the latter as implemented by some of the book's contributors. The reader can now evaluate each of the variants and decide whether one option is more convincing than another. This, I believe, can help clarify the debate on analytical sociology and foster further discussion.

Indeed, the ambition behind *Analytical Sociology: Actions and Networks* has been to contribute to the future of analytical sociology and to strengthen the connection between analytical sociology and the rest of sociology. To this end, I shall close the book with some remarks on what I believe to be the importance of analytical sociology for the future of sociology at large.

As discussed in the book's introductory chapter, the main contention of the critics of analytical sociology is that it does not constitute an original research perspective within contemporary sociology. Apart from the specific problems that I discussed at length in the introduction, this objection raises a more fundamental question: what counts as a scientific innovation? The epistemology and the history of sciences suggest that this is not a trivial matter. Unfortunately, critics of analytical sociology do not specify the conception of scientific innovation and change that lies behind their denial of analytical sociology's novelty.

At the outset, I stated that my specific understanding of analytical sociology is that it is a research program in the sense of Lakatos. Accordingly, I now also follow Lakatos's recommendation to consider scientific innovation in terms of a "problem shift" (see Lakatos, 1972: 154–159, 173–177). According to this view, science does not evolve on the basis of sudden, abrupt, radical changes; rather, it does so through smooth and progressive viewpoint modifications. In the short run, small, not big, discontinuities constitute, according to Lakatos, the evolution of science. A "paradigm shift," by contrast, can only be ascertained a posteriori and in the very long run. In sociology, the epistemology of Abbott (2001: Ch. 1) contains a similar conception of novelty: "The new ideas are always the old ideas under new labels. The new people are the old people in new roles" (p. 26), he notes, and a couple of pages later he writes: "Interesting new social science can always be produced by trying a combination hitherto unknown" (p. 29). Recall that the interdependence among existing elements is precisely the criterion that I suggested in my introductory chapter to characterize analytical sociology's distinctiveness.

Indeed, several "problem shifts" have already been generated by analytical sociology. The essays collected in *Analytical Sociology: Actions and Networks* suggest four of them. First, analytical sociology is modifying one of the dogmas on which part of the individualistic tradition has traditionally been based: namely, the analytical priority given to the postulate of rational action. Second, analytical sociology is modifying the perception of the scope that can be reasonably attributed to multivariate statistics. Third, analytical sociology is fostering a more explanatory way to conduct the analysis of social networks. Fourth, analytical sociology is incorporating into its core simulation-based methodologies that until recently were the preserve of computer scientists, physicists, or biologists. The first problem shift is a consequence of analytical sociology's commitment to the principle of realism, whereas the last three are all consequences of analytical sociology's quest for better tools with which to implement and test substantively oriented generative models.

In my opinion, these problem shifts are at present more local than general, in that they tend to be relevant and visible in some areas of contemporary sociology more than in others. They are far from going unnoticed, however. As noted by one recent discontent with analytical sociology, "AS may in fact has nothing to do with 'sociology' as traditionally defined"

(Lizardo, 2012: 8). Thus, strangely enough, (some) critics implicitly admit that analytical sociology has the capacity to generate considerable "problem shifts" but at the same time deny its distinctiveness with respect to sociology at large.

There are good reasons to expect that the "problem shifts" generated by analytical sociology will become increasingly important and visible in the future. The argument that I shall defend is that analytical sociology is a promising intellectual resource for sociology because both the concept of mechanism and the most powerful formal tools with which to study models of mechanisms possess two analytical properties that give analytical sociology the potential to foster theory construction by combining small analytical blocks into more and more complex explanatory constructs. "Genericity" and "fractality" are the two properties at the origin of this "Lego approach" to sociological theory. In my opinion, they constitute the ultimate epistemological justification for the interest of analytical sociology.

Let me start with the notion of "genericity." As noted in the introductory chapter, the notion of mechanism is substantively empty. As long as one does not look for mechanisms underlying specific high-level regularities, the content of a mechanism (i.e., the entities, their properties, activities, and connections composing the low-level system responsible for the high-level behavior) remains unspecified. This means that the concept of mechanism can travel across research domains, and that it can be adapted to the specific topic under scrutiny. In the field of sociology of science and technology, material devices with the properties of being malleable, adaptable, and transversal to specific application domains have been called "generic instruments." It has been proven that they are at the origin of most of the technical innovations that have changed our everyday lives (see Joerges and Shinn, 2001).

A mechanism can be conceived as a "generic conceptual instrument." In this respect, its main strength is that scholars with different theoretical orientations and research interests, even ones belonging to different disciplines, can communicate in terms of mechanisms by using the general language of entities and their properties, activities, and connections. This may increase communicability among scholars, idea exchanges, and knowledge accumulation. In particular, the "genericity" of the notion of mechanism may help uncover mechanism commonalities across social domains and, to borrow the terminology of Elster (2007: Ch. 1), help combine "atomistic" mechanisms into progressively more complex "molecular" mechanisms.

In my view, *Analytical Sociology: Actions and Networks* has illustrated this potentiality. It has done so, for instance, when hypotheses from structural balance theory have been combined with the homophily principle and with ideas from threshold models; when the perspective of "e-state structuralism" has been extended to apply to informal groups in which one-to-all interactions are very frequent, as in online forums; when ideas from the statistical analysis of longitudinal data analysis have been extracted from their original context to gain better understanding of the connection between group size and level of homophily; or, when local and global properties of social networks have been combined to determine actors' opportunities in the jobs market. I am not claiming that this dynamic of theory construction is new or exclusive to analytical sociology (on the concept of "theory consolidation," see Merton, 1967: 68; on that of "theoretical synthesis," see Fararo, 1989; 2001; on that of "modular theory," see Markovsky, 2010). More modestly, I am suggesting that using a "generic" concept, that of mechanism, which is intrinsically able to travel across application domains, can foster this dynamic of theory construction and, consequently, of problem shifts.

The second analytical property of the concept of mechanism, that is, "fractality," should amplify this dynamic. As discussed in the introductory chapter, the epistemic purpose

of formulating models of mechanisms is to clarify how a given connection has come about. A mechanism-seeking research strategy thus only contains a "generic" rule: when one is puzzled by a connection, one should try to break it down by dissecting the entities and their properties, activities, and connections that may have generated the connection at hand. The rule is "generic" exactly in the sense defined above: it can be applied, adapted, and reshaped as long as new connections to be understood appear. As a consequence, mechanism-based thinking potentially triggers self-similar theoretical constructions.

A model that, say, aims to explain the aggregate-level structure of the connection between actors' socio-economic backgrounds and their educational outcomes may initially refer to a set of entities (actors) with their properties (say, perception of education costs and of cognitive ability), activities (say, finding a balance between cost perception and ability), and connections (networks among the actors) in an attempt to generate the aggregate-level connections. One may then judge that the connection between actors' properties and activities, for instance, has been posited but not explained. Consequently, one may refer to another set of entities (beliefs) with their properties (say, cognitive salience and emotional strength), activities (logical deductions/inferences from the given entities), and connections (networks among beliefs) in an attempt to endogenize the initially posited connection between actors' cost/ability perceptions and the final compromise that they establish among them. If one makes the effort to continue this connection-breaking activity further, it appears that, by iterating the same rule, one ends up with a theoretical structure that at each level seems formally similar. Each connection, in fact, is thought to be the possible result of bundles of new entities with their properties, activities, and connections.

In this sense, the concept of mechanism can be conceived as possessing a "fractal" nature. Self-similarity and function iteration are indeed the two fundamental features of mathematical objects known as "fractals" (for a deep but mathematically accessible introduction, see Feldman, 2012; for an illuminating application to the history of sociological ideas, see Abbott, 2001).

In my view, the "fractal" nature of mechanism-based thinking should foster problem shifts in sociology in at least three ways. First, it may help the development of multi-level explanatory models. Second, it may encourage theory networking and help sociologists to collaborate with other social (or natural) sciences: connections at different levels of analysis may require the mobilization of sets of entities/properties/activities/connections for which different disciplines have different skills. Third, conceiving generative models as self-similar theoretical objects may induce development of a radically new conception of explanatory power. Similar to the "dimensionality" of mathematical "fractals" – qualitatively speaking, the amount of self-similarity characterizing a fractal object (see Feldman, 2012: Ch. 16) – a generative model's explanatory capacity may be conceived in terms of the number of connections that the model is able to break down.

It is to be noted that "genericity" and "fractality" do not characterize only the concept of mechanism; they also characterize that of "computational objects," these being the fundamental components of agent-based modeling, which is the most flexible method for the formal design of models of mechanisms. As discussed in the introductory chapter, the basic units programmed and manipulated within an agent-based model are as substantially empty as the concept of mechanism. A computational object assumes a specific meaning only when a specific set of properties and rules of behavior (technically, functions, methods, or procedures) are associated with it. This means that "collections" of "classes" of "objects" can be used to implement any sort of substantial generative model containing hypotheses on

whatever set of entities/properties/activities/connections. Detailed historical analyses of objected-oriented programming, in fact, have demonstrated that object-oriented programming and the simulation methods based on it have traveled (and travel) across application domains because of this infinite malleability typical of "generic instruments" (see Shinn, 2007).

On the other hand, as in the case of "mechanism," "genericity" implies "fractality." Within the object-oriented paradigm, since everything can be "objectified" as soon as a given class of objects is created to represent a given set of entities/properties/activities/connections, another class of objects representing another set of entities/properties/activities/connections can be created to better ground the behavior of the first posited class of objects. For instance, if a given class of objects represents the properties and the activities of a population of actors, the brain functioning of each actor may be modeled by means of another class of objects representing neurons, their properties, activities, and connections; and one can let the two classes of objects depend on and communicate with each other. This is precisely what is done, for instance, when an agent-based model at the actor level is coupled with an agent-based model at the infra-actor level (as in the case of artificial neural networks) (see, for instance, Hayward, 2006). Thus, object-based computational models are self-similar constructs exactly like the generative models that they attempt to implement.

It should now be clearer why the specific understanding of analytical sociology on which *Analytical Sociology: Actions and Networks* is based can be regarded as being the one best able to trigger the largest set of "problem shifts" in the long run. The point is that its conceptual and methodological units share the same properties, that is, "genericity" and "fractality." Thus, what may seem only theoretical potentialities related to these analytical properties can translate into concrete opportunities for "problem shifts" because "generative models" can be implemented and studied within a specific methodological framework, that is, object-oriented, simulation-based models which also share "genericity" and "fractality."

Is this proposal "excessively ambitious?" According to the provocative analysis of Elster (2009), "excessive ambition" characterizes the quantitative approaches in economics, sociology, or political science that endeavor to establish law-like regularities and that build on rational-choice mathematical models by ignoring the substantive unrealism on which these models are based, and/or on multivariate statistical techniques by ignoring the complex set of assumptions under which these techniques lead to reliable estimations, and/or by giving causal, substantial interpretations to the model's coefficients where these coefficients only summarize data.

The quantitative-oriented variant of the analytical sociology research program discussed throughout *Analytical Sociology: Actions and Networks* seems to be protected against these dangers. First, it is clearly committed to the formulation of generative models mimicking mechanisms, and it looks for generality in the operation of similar mechanisms in different social domains. Hence it is not primarily interested in discovering law-like regularities. Second, it is committed to the principle of realism that has induced several scholars to look for action-related mechanisms that are experimentally and empirically grounded. It thus resists the formal appeal of neoclassical rational-choice theory and explicitly values models of heuristic-based decision making. Third, it explicitly endorses a critical stance on the scope of multivariate statistics, and it argues that models of mechanisms cannot be implemented and fully tested within the variable-centered framework. It is consequently protected against the risk of equating robust correlations with detailed micro-founded explanations. Fourth, it proposes a methodological tool with which to implement and study models of mechanisms, that is, agent-based computational models able to represent actors of all kinds and the

interdependence structures among them. Thus it is not constrained to choosing hypotheses on the basis of their mathematical tractability. Finally, it proposes the injection of as much empirical and experimental evidence as possible into the artificial mechanisms designed to prove that, once they are data driven, these mechanisms are still able to generate the regularities that one is seeking to explain. It consequently attempts to control for the possible lack of robustness of the methodology in that it proposes to recreate *in silico* the connection between the low-level mechanisms and the high-level regularities that are postulated as existing in reality.

Analytical Sociology: Actions and Networks is indubitably not the book that will convince skeptics that this kind of analytical sociology is an original, promising, and viable research program for the future of sociology. Hopefully, the efforts that all the contributors have made to relate their own research agendas to that of analytical sociology and my own effort to relate their contributions to a specific understanding of analytical sociology indicate at least a modestly ambitious direction for further discussion. This has been the ambition behind *Analytical Sociology: Actions and Networks*: to contribute to the development of the future of analytical sociology, rather than discuss its past or polish and police its present boundaries.

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