

Faculty of Business Studies and & Economics  
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# A systemic framework for the computational analysis of complex economies

An evolutionary-institutional perspective on the ontology, epistemology, and  
methodology of complexity economics

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# Chapter 1

## Introduction: A fundamental framework for the analysis of complex economies

### Chapter Abstract

This introductory paper introduces the idea of a symbiotic relationship between evolutionary-institutional and complexity economics. It consists of two main parts:

The first part focuses on how the emerging research program of complexity economics can benefit from evolutionary-institutional theory and begins by showing that complexity economics still lacks an adequate philosophical foundation. I explicate why such a foundation is needed if complexity economics is to promote further scientific progress and that such a foundation must consist of an adequate *ontology*, *epistemology*, and *methodology*. The following parts of the paper then draw upon institutionalist and social theory to develop these three aspects: I derive a definition of complex economic systems by identifying their essential properties. I then propose an epistemology that is based on the concepts of *mechanism-based explanation*, *generative sufficiency*, and an extended version of Uskali Mäki's concept of "Models as Isolations and Surrogate Systems". I continue with some methodological considerations and argue that the method of *Agent based computational economic modeling* must play a distinctive role for the analysis of complex economies.

The second part of the introductory paper anticipates subsequent chapters by sketching how evolutionary-institutionalism can profit from a methodological transfer from complexity economics. In particular I argue that the method of Agent based computational modeling can advance institutionalism both as a formalization device and by providing theoretical concepts that are useful for institutionalist theorizing itself. Then I give a short overview on the chapters that follow and explain their mutual relationships.

The introductory paper closes by discussing a potential convergence of evolutionary-institutional and complexity economics and gives an outlook on avenues for further research.

## 1.1 Introduction

This thesis deals with the symbiotic relationship between evolutionary-institutional and complexity economics. In this sense, this introductory paper and the following four chapters are complementary to each other: the chapters put their focus on how institutionalism can benefit from the application of complex systems methods, and the introduction complements them by focusing on how complexity economics can benefit from exploiting the reflective nature of institutionalist theory and its implicit systemist foundations (see also figure 1.1 below).

While evolutionary-institutional economics has a very long tradition in economics and dates back to the works of Veblen, Commons, and Mitchell, among others, the research program of complexity economics is relatively new. It emerged from the workshop on *Evolutionary Paths of the Global Economy* in 1987 at the Santa Fe Institute (SFI) and is now considered a most innovative and promising, but also a still premature area of economic research: while the research community has developed an impressive body of formal, particularly computational, modeling techniques suitable for the analysis of complex systems, there is only very little work on the philosophical underpinnings of these models: what does it mean for the economy to be complex? Why exactly should we use advanced simulation techniques to study a complex economy? How can two complex models be compared concerning their explanatory content? And finally, what is the essence of a complexity approach to economics? There is neither much explicit consideration of these questions nor a systematic way in which these questions are approached by complexity economists.

But these fundamental questions must be answered if further progress in the research program of complexity economics is to be made. If they are not answered properly, the community will run the risk of becoming fragmented. First symptoms of such a development are already observable: many researchers working on complexity economics have very diverse backgrounds, have very different conceptions of what economic models should do and how they should be designed.

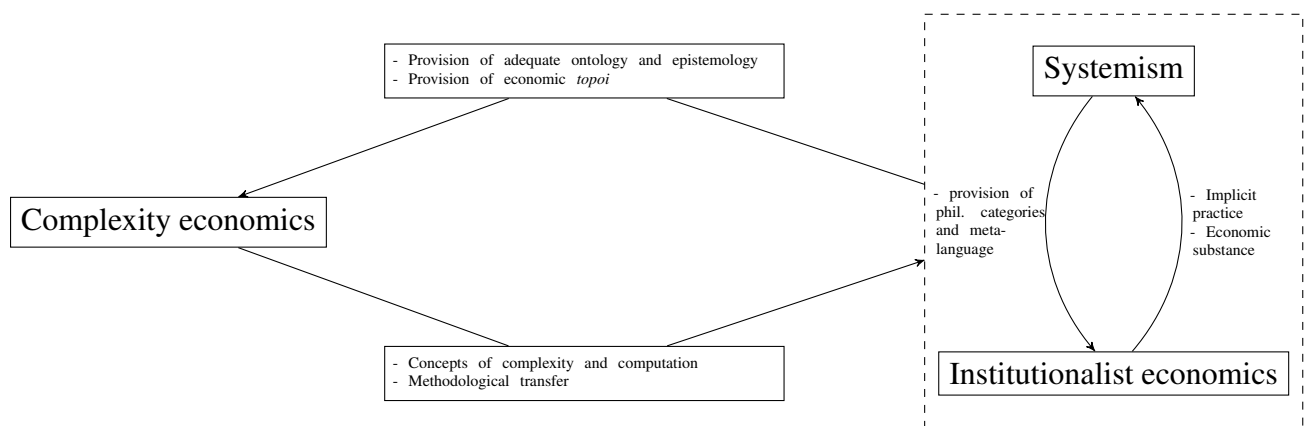


Figure 1.1: An illustration of the knowledge transfer between institutionalism, systemism, and complexity economics.

There is no common denominator through which these (formally very elaborated) models are related, other than the (ambiguous) claim that they analyze the economy as a complex system, a statement that can be interpreted very differently. As an example, consider the claims of the two subsequent leaders of the complexity economics research program at SFI, Brian Arthur (1988-1989 and 1995) and Steven Durlauf (1996-1998). Brian Arthur argues that

...this new approach is not just an extension of standard economics, nor does it consist of adding agent-based behavior to standard models. *It is a different way of seeing the economy.* [...] This view, in other words, gives us *a world closer to that of political economy than to neoclassical theory*, a world that is organic, evolutionary, and historically-contingent. *Equilibrium economics is a special case of nonequilibrium and hence complexity economics*, therefore complexity economics is economics done in a more general way. (Arthur (2015, p. 2) italics by CG)

He thus makes a clear distinction between complexity and neoclassical economics since the two differ from each other in very fundamental ways. In particular, he considers neoclassical economics as a particular special case of complexity economics where most fundamental and interesting economic issues - such as the absence of an equilibrium or the impossibility to calculate rational expectations - are simply not apparent and can be neglected. Steven Durlauf, on the other hand, argues that complexity economics only represents a one special case of neoclassical economics. In the introduction to the conference proceedings of the annual meeting of the complexity economics research program he writes:

The models presented here *do not represent any sort of rejection of neoclassical economics*. One reason for this is related to the misunderstanding of many non-economists about the nature of economic theory; simply put, the theory was able to absorb SFI-type advances *without changing its fundamental nature*. Put differently, economic theory has an immense number of strengths that have been complemented and thereby enriched by the SFI approach. (Blume and Durlauf (2006, p. 2), italics by CG)

This view entails a very different epistemological, ontological, and methodological position than that of Brian Arthur. The fact that both consider themselves, and are considered, as leading complexity economists is only one example of the diversity in the field.

The first central contribution of this thesis addresses the resulting ambiguity by supplying an overall framework that helps to structure this diversity and to answer the fundamental questions posed at the beginning. As such it contributes to a unifying starting point for research dealing with economic complexity. This unifying starting point consists of an *ontology, epistemology, and methodology* for the analysis of complex economic systems. All three concepts are necessary and closely related: there can be no epistemology of something of which we do not know what it is - therefore we need to develop an adequate definition (and thus an ontology) of complex economic

systems. There can be no fruitful methodological discussion if it is not clear how knowledge can be created, which is why the epistemology is needed. And knowing that something exists, and how one could in principle acquire knowledge about it is useless if the adequate tools are not at one's disposal - therefore, an adequate methodology is also required.

This contribution of the thesis therefore puts complexity economics on sound theoretical footage.

The second central contribution is related to the path that is taken to achieve this first aim: In developing this framework for complexity economics, I will draw on insights from evolutionary-institutional economics. Evolutionary-institutional economics has itself experienced a number of important and productive reflections on its ontological and epistemological base and it can now be considered one of the most reflective and - in this sense - richest paradigms in economics. Much knowledge may be carried over to an emerging research program such as complexity economics.

Additionally, many evolutionary-institutional economists themselves implicitly consider the economy to be an evolving complex system. But the modern literature on economic complexity, in particular the formal approaches advocated therein, does not play any distinctive role in the classical and most contemporary writings of institutional economics.<sup>1</sup> The two research programs were largely separated from each other and even today there are only some very few exceptions who are actually aware of this implicit relation (examples include Elsner (2012), Bowles (2014), Elsner, Heinrich, and Schwardt (2014), or Arthur (2015)). Using evolutionary-institutional economics as a starting point for a philosophical underpinning for complexity economics will therefore reveal a number of complementarities among these research programs and will prove useful in modernizing the very conservative methodological base of evolutionary-institutional economics itself. This is a similar strategy to that of Elsner (2012) for the method of (evolutionary) game theory: just as game theorists can profit from the sound epistemological base of institutionalism, evolutionary institutionalism profit from the formal methods provided by game theorists.

Lastly, it is one of the fundamental research objects of evolutionary-institutional economics, social institutions, that constitutes an important argument for why we actually should consider the economy to be an evolving complex system in the sense advocated in this thesis. This closes the circle back to complexity economics: I will show that there is a potential symbiosis among evolutionary-institutional and complexity economics that simply needs to be identified, understood, and exploited. The development of a systematic framework for the computational analysis of complex economies will therefore lead to a vision of a coherent and promising research area that exploits the mutual complementarities among evolutionary-institutional and complexity economics and paves the way for most promising avenues of future research. This is

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<sup>1</sup>This also relates to the question of the relation between evolutionary-institutional and modern evolutionary, or neo-Schumpeterian economics. I discuss this matter in more depth in section chapter 4.



the second major contribution of this thesis.

The roadmap for the rest of this introductory paper is the following: The first three sections are about the ontology (section 1.2), epistemology (section 1.3), and methodology (section 1.4) of complex economic systems.

After this general framework for complexity economics is established, I anticipate the following chapters by giving an overview about how evolutionary-institutional economics can benefit from the theory of complexity in section 1.5. Section 1.6 then gives an overview over the chapters that follow. The final section then provides a summary of what has been accomplished in this introduction, and, more importantly, gives an outlook on further lines of research that can be based on the research program constituted by this thesis.

## 1.2 Ontology: What is a complex economic system?

### 1.2.1 The need for an ontological starting point

Clearly any such awareness [of the fact that the basic (deductivist) method of mainstream economics is inappropriate to its subject matter] presupposes a prior analysis of the nature of social phenomena - as does any project of developing an alternative. Fleetwood (2002, p. 129), note by CG.

If one advocates a complexity approach to economics, one must be able to answer fundamental questions such as “What is complexity?” and “What makes an economic system complex?”.

Being able to answer such questions is important because shared meanings are a necessary prerequisite for communication and mutual understanding among members of the scientific community (see also Hodgson (2015, p. 26)). If there is no mutual understanding of what the particular property that constitutes a complex economic system as such is, then *complexity* is a poor starting point for a research program and complexity economics is not likely to promote scientific progress. The reason is that without a shared language, meanings, and understanding of the objects under investigation, researchers will inevitably work in parallel and separately, rather than referring constructively to each others works.

Unfortunately, the current literature does not provide satisfactory answers to the question of what a complex economic systems is: Usually, either very general, *semantic* definitions, such as “a complex economic system is characterized by heterogeneous agents that act in an interdependent manner”, or very specialized *quantitative* definitions of certain aspects of a social system, such as “the decision problems of the agents in the system under investigation are *NP*-hard and thus impossibly decided in polynomial time”, are used. While the semantic answer usually remains very vague, quantitative answers are often too specific to justify a *general* approach of complexity economics.

Another answer is the reference to the universality of power laws in important economic quantities which, at least in statistical physics, often occur in out-of-equilibrium systems and systems in a state close to criticality.<sup>2</sup> But on top of the problem of just applying theoretical concepts from physics to social and economic phenomena,<sup>3</sup> there are at least two additional problems with such an approach of motivating a complexity approach with reference to power laws: firstly, it is very difficult to identify power laws empirically and data is usually difficult to obtain. The field of economic networks is a very good example to illustrate this: for some time there was huge excitement about a universal property of real world networks, namely to have scale-free degree distributions. But after some time scientists became skeptical of whether these degree distributions were really scale-free or not. And for most cases, there was not enough data to reach a reliable final conclusion (Clauset, Shalizi, & Newman, 2009; Mitchell, 2009; Shalizi, 2014). Secondly, even if a power law can be identified, this fact in itself does not tell you anything about the underlying mechanisms because “there turn out to be nine and sixty ways of constructing power laws, and *every single one of them is right*, in that it does indeed produce a power law.” (Shalizi, 2014). So having identified a power law can ‘only’ be a first step of understanding a system: because the power law could have emerged for very different reasons, a next step must be to identify the particular mechanisms that have produced the power law.<sup>4</sup> Of course, power laws may hint at processes of self-organization and certainly limit the number of candidate mechanisms operating in the system - but they should not be taken as sole evidence for showing a system to be complex (Solow, 2005). Thus, all these answers on what constitutes a complex system in the context of economics are unsatisfactory.

The reason why there is no satisfactory explanation of what is a complex economic system is the absence of any elaborated *ontological basis* for the analysis of economies as complex systems. There has been enormous and impressive progress in studying economies from a complexity perspective, but the corresponding studies were mostly motivated by the interdisciplinary interest of the researchers, or the examples of past successes of such an application. I do not deny that the semantic justification of many heterogeneous and interdependent agents hints at an essential ontological aspect of economies that justifies a complex systems perspective. But what is needed is a general ontological and epistemological motivation to take the complexity perspective on social systems. Simply applying concepts from the natural sciences to the social sciences is not enough.<sup>5</sup> We therefore need a theoretical motivation for the study of economies as complex

<sup>2</sup>For more information on this see Landau and Lifshitz (2013).

<sup>3</sup>I am not arguing against interdisciplinary cooperation among physicists and economists - to the contrary. But if we wish to apply concepts from physics (or any other scientific discipline) in economics, we should do this with good reasons. Here I argue that the reference to the (alleged) universality of power laws in economic data is in itself not a sufficient reason.

<sup>4</sup>Mitzenmacher (2003) provides a nice (but non-exhaustive) list for generative mechanisms that all produce power law distributions.

<sup>5</sup>In fact, this has done great harm to scientific progress in economics: much of the now outdated parts of neoclassical theory were built upon concepts imported from physics. And the unreflected import of biological analogies such as ‘natural selection’ to economics also seems to be rather counterproductive (Cordes, 2006).

systems that is grounded in and based on social theory. Developing this perspective from an evolutionary-institutional perspective turns out to be particularly promising: firstly, evolutionary-institutional economics is well grounded in social theory<sup>6</sup>. Secondly, in chapters 2 and 4 I identify the systemist foundations of evolutionary-institutional economics. This concept of *systemism* also serves as a very good vantage point for developing an ontology (and epistemology) for complexity economics.

### 1.2.2 The ontological essence of complex economic systems

What is required is the identification of the *essence* of *complex* economic systems. The word *essence* has a well defined theoretical meaning in the social sciences:<sup>7</sup> “The essential properties of an entity of a particular kind are those properties of the object that it must have if it is to be an object of that kind.” (O’Neill, 1998, p. 9). We may therefore distinguish *essential* from *accidental* properties which a thing might have, but the loss of which would not make the thing become a thing of a different kind. Identifying the essential properties of a thing and elaborating an adequate definition of it is therefore a question of *ontology*. We will see, however, in the next section that the definition of complex economic systems, and therefore the provision of a very general ontological basis for their analysis, has some straightforward epistemological and methodological implications that can be exploited. But before we turn to this next step, we must find an ontological definition of a complex economic system.<sup>8</sup> Such a definition must include the essential features that make a complex economic system what it is, and what demarcates it from both non-complex social systems and from non-social complex systems.

The first obvious step in reaching such a clear definition of complex economic systems is to clarify what is meant by a *system*. I argue more extensively in chapter 2 that a useful starting point is the assertion of Bunge (1996) according to whom *any* object or entity is either “a system or a part of one”, and that every component of a system “is connected with other parts of the same object in such a manner that the whole possesses some features that its components lack - that is, emergent properties” (Bunge, 1996, p. 20).

A system thus consists of parts, and relations among these parts: whenever we perceive something as being composed of parts, we can speak of a system.

Interestingly, for Bunge, the concept of a system is inextricably linked with the concept of a *mechanism*. Mechanisms are essential elements of any system and express themselves “as a process (or sequence of states, or pathway) in a concrete system, natural or social” (Bunge, 2004, p. 186). This means that every system has an associated set of relations, determining its

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<sup>6</sup>With ‘social theory’ I mean all the sciences that consider themselves generically devoted to studying society, i.e. social philosophy, sociology, political sciences, (parts of) economics, anthropology, history, etc.

<sup>7</sup>For a more detailed exposition of *essentialism* and its relevance to the social sciences see e.g. Hodgson (2015).

<sup>8</sup>To show that ontology cannot be reduced to epistemology is one of the central achievements of critical realism. Since Bhaskar (1975) the reduction of *being to knowledge about this being* has been known as the *epistemic fallacy*. For a further discussion on this matter and its relevance to economic research see Archer (1995) or Lawson (2003).

relational structure, and a set of particular mechanisms. We will therefore say that a system is complex if its relations and mechanisms are of a particular kind.

But Bunge's systemism is not very helpful in determining these particular properties as it does not offer any explicit treatment of the concept of complexity. I will therefore substantiate the particular kind of relations and mechanisms with a reference to the physicist and philosopher Warren Weaver, who gave a very illuminating distinction between simple and complex *problems*.<sup>9</sup> In this context he comes up with a definition for problems of *organized* complexity: according to Weaver (1948), problems of organized complexity include a moderate number of variables (more than two, but less than several billions) amongst which a certain degree of *organization* exists. This means that these variables are not disorganized, such as the million particles making up a gas that may conveniently be described with a Brownian motion. The variables Weaver has in mind show a certain kind of internal organization, i.e. a particular configuration of their relations, so that, taken together, they make up an *organic whole* (Weaver, 1948, p. 539).

It is important to note that Weaver did not use the word 'organic' with any particular biological (e.g. ontogenic or phylogenic) analogy in mind. Rather he used it to clarify that the parts systems characterized by organized complexity "are in close relation" (Weaver, 1948, p. 537).

He provides an illustrative example for what he means by this when he asks "why one chemical substance is a poison when another, whose molecules have just the same atoms but are assembled into a mirror-image pattern, is completely harmless". This example highlights well the importance of the relational structure of the molecules. To accentuate this focus on the relational structures and in order to avoid confusion about whether the notion of an *organic whole* should have any particular biological meaning (i.e. a phylogenetic or ontogenetic analogy, see e.g. Dopfer and Potts (2008, p. 20)), I will use the term *systemic whole* instead.

I now propose to combine Weaver's classification of *problems* with Bunge's concept of *systems* to reach an intermediate ontological definition of a complex economic system: an economic system is complex if it consists of parts, among which their relations are organized so that they make up an *systemic whole* (Weaver, 1948, p. 539) and that this whole possesses some features that its components lack (Bunge, 1996, p. 20).

But this intermediate definition leaves two important questions still unanswered: Firstly, what does it mean that the parts must be organized so that they make up an systemic whole in the sense that the parts of the system are related closely to each other? Do the relations between the different parts somehow need to be special? And secondly, what is the source for this organization? Must it necessarily be endogenous in the sense that it results from the processes of the system itself (i.e. its mechanisms)? We will turn to these two questions one by one.

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<sup>9</sup>The distinction is discussed in more depth in chapters 2 and 4.

**Scrutinizing the relational structure of complex economic systems**

Weaver is very clear when the nature of the relations is concerned: if the relations are such that they do not follow any particular order, but still lead to emergent properties, then we do not speak of organized, but *disorganized* complexity (Weaver, 1948, p. 537). Weaver uses the example of a gas where there are a considerable number of variables (i.e. position and velocity of any particular molecule), but because the interactions between the variables smooth each other out (i.e. when one molecule hits another, position and velocity are altered in a simple additive fashion), the overall distribution of the gas can be described via the behavior of the *average* molecule: the pressure of a gas, for example, depends on the average force of the molecules and the size of the container in which the gas is located.

This is a situation with no particular *interdependence* between the single elements of the gas, or, in mathematical terms, the *superposition principle* holds.<sup>10</sup>

Therefore, no exact knowledge of the mechanism on the micro level is required: we do not need any theory about the precise movement of any single molecule, because taken together and thanks to the superposition principle, a regular statistical distribution describing their movement in a statistical manner *emerges* and information in terms of the average molecule is useful to describe the behavior of the whole.

This phenomenon can be captured more generally if we consider a random variable  $X$  that has mean  $\mu$ : we may not know what the next individual realizations of  $X$  will be. But if we have a large number of realizations, and the realizations are *independent from each other*, then we know that the distribution of the many realizations almost certainly has mean  $\mu$ . This is true thanks to the *absence* of any dependence of one realization of  $X$  to another. Also, when aggregating the single realizations into an average, the particular small realizations smooth out the particular large realizations.

Much of conventional economic theory assumes the economy to be a system that is characterized by such a kind of disorganized complexity. But this is not what is meant by a complex system in this thesis. I refuse to use the label ‘complex system’ for such systems because this would broaden the concept to an extent where it loses any significant meaning.

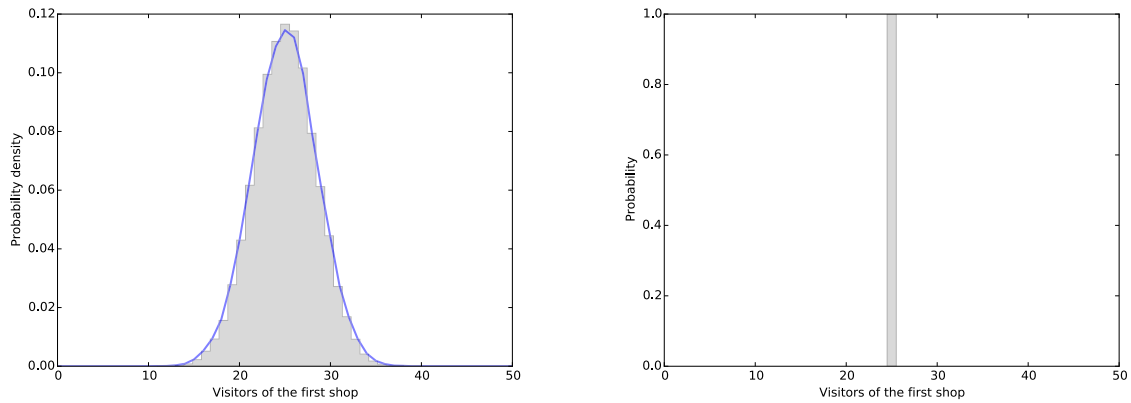
Rather, I use Weaver’s idea of disorganized complexity as a demarcation: for an economic system to be complex, the relations between its parts must be non-trivial so that interactions depend on each other. Consider the following example based on Miller and Page (2007):

50 people need to decide sequentially whether they go in one of two different shops. If there is no direct interaction among the individuals, and people have no particular preference for either of the two shops, then the agents make their decision randomly and pick either shop with equal probability. The result is plotted in figure 1.2a: the number of visitors for each shop will follow approximately a normal distribution with mean 25.

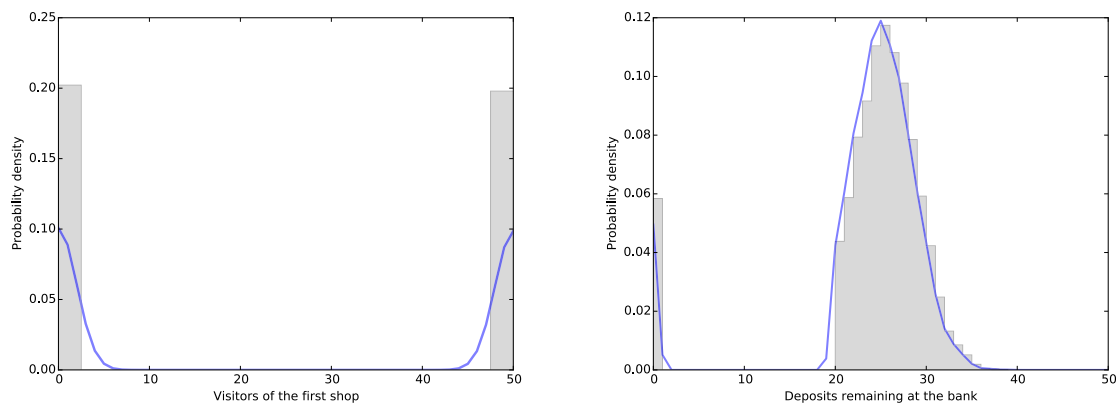
If there is direct interaction among the individuals, and each individual tries to go to the shop

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<sup>10</sup>A system obeys the superposition principle if the equations describing its behavior have both the property of *additivity* (i.e.  $f(x_i) + f(x_j) = f(x_i + x_j) \forall i, j$ ) and *homogeneity* (i.e.  $f(a \cdot x) = a \cdot f(x)$ ).



(a) The resulting distribution of independent agents choose each shop with probability 0.5. (b) The resulting distribution of interdependent agents try to get into the less frequented shop.



(c) The resulting distribution of interdependent agents try to get into the more frequented shop. (d) The resulting distribution for the example with the bank.

Figure 1.2: The resulting distributions and kernel estimations for 500 runs of the respective experiments.

visited by fewer people, then the system will equilibrate with *exactly* 25 people going to each shop - with no normal, but a degenerate distribution (1.2b). However, if people try to go to the shop where most of the people go, then all people will *certainly* go to the same shop, resulting in a two-peaked distribution (see figure 1.2c).

The last situation is representative of a wide range of social phenomena where the existence of positive feedback (e.g. through the existence of network effects) renders the study of average individuals rather misleading. Consider the case where the 50 agents now go to a bank to withdraw currency with probability 0.5 for each agent. Suppose the bank holds enough deposits to cover the withdraws of 30 people. If more than 30 people try to withdraw their money, the bank risks bankruptcy causing all agents to panic and withdraw their money. The resulting distribution of remaining deposits follows a normal distribution up to the threshold of 20, then all the remaining probability density goes to the lower end of the distribution, see 1.2d.

Thus, if one considers the resulting distributions of the four situations, it becomes immediately obvious that as soon as direct interdependence between the agents enters the picture, and the interactions among the agents do not follow linear patterns, then the overall behavior of the system changes dramatically.

In this kind of situations the superposition principle fails and the dependency structure among the different parts becomes important. It is no longer possible to simply add up the behavior of individual parts (or small subgroups) to get an adequate description of the whole, and simply averaging over the individuals does not work out anymore. Consequently, the assumption of the *representative individual* (which is in some sense an average individual) becomes misleading and alternative modeling approaches must be taken into consideration (Kirman, 1992).

### **Self-organization as a constituent feature of complex economic systems**

The second open question with regard to our preliminary definition of a complex economic system concerns its degree of self-organization: how does the organizational structure among the parts of the system emerge? To tackle this question from the opposite direction, we may ask whether an economic system that is entirely controlled by one central authority is actually conceivable? In reality, such systems are practically not existent.<sup>11</sup> All existing economic systems are to some extent *self-organized*: the organization of the relations among the parts (most of the time the economic agents) emerged endogenously from the dynamics of the system. Of course, there has always been strategic link creation and destruction by a central entity, but this is mostly driven by the decisions of the agents themselves. There are, of course, examples of where a centralized institution such as the state or a powerful corporation is able to control link creation and destruction among the economic agents, but there is certainly no case in which such a control is absolute. This means that for a theoretical conception of complex economic systems, it is easy to stay agnostic of whether the organization among the parts of the system emerged in a decentralized manner or during a centralized process: it is an empirical necessity to allow for decentralized link formation and destruction in all socio-economic systems.

That being said, why is accounting for self-organization so important? It turned out that the particular kind of self-organization has often important consequences for the micro and macro dynamics of the systems under investigation. The resulting dynamics are often very different from those predicted by equilibrium models.

For example, conventional economic theory based on the equilibrium concept has severe problems in accounting for the size distributions of firms which frequently follows a Zipf distribution (Fujita, Krugman, & Venables, 1999; Axtell, 2001; Heinrich & Dai, 2014). The

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<sup>11</sup>One may think of the hypothetical economy of the canonical general equilibrium model of Arrow and Debreu (1954) with its Walrasian auctioneer who calls out a price vector bringing the economy to a competitive equilibrium. But note that this is a *model* and thus a *hypothetical* economy. The question of whether we can learn something about real economies via such model constructions is a question of epistemology rather than ontology and is discussed in section 1.3, and chapters 3 and 5.

reason may well be that the processes generating these distributions represent some form of self-organization: Axtell and Florida (2006) propose a model whose macro behavior replicates the Zipf distribution both for city size and firm size. The model is based on autonomous agents interacting directly with each other forming cities and production teams within a spatial setting. The resulting size distribution is thus the consequence of the kind of self-organization resulting from the interaction among the individuals.<sup>12</sup>

This example shows that self-organization seems to be not only an important aspect of real economies, it also seems to have very relevant implications.

### 1.2.3 Summary: The ontological essence of complex economic systems

We now have a useful ontological working definition of a complex economic system:

An economic system is complex if it consists of potentially heterogeneous and potentially adapting parts, among which their relations are (at least partly) self-organized such that they make up an *systemic whole* in the sense that the interactions among the parts are nonlinear and that this whole possesses some features that its components lack.

Two further qualifications have been added: the qualification of potentially heterogeneity has been added because it usually makes a huge difference whether one considers homogeneous or heterogeneous building blocks for a system (Kirman, 1992). While complex economic systems with homogeneous parts are potentially conceivable, they are empirically insignificant. There is, however, no reason to *a priori* exclude them from the definition. The same holds true for the qualification of potentially adaptivity of the parts: most economic (sub)systems and parts (e.g. agents) are constantly evolving and thus adapting, a fact that cannot be captured with conventional economic theory (Lucas, 1976; Farmer, 2012) but plays a central role in complexity approaches to economics (Arthur, 2011).

The resulting definition is theoretically well grounded in the social theory on systems and the theory on complexity. It is the ontological basis that underlies all the chapters that follow and it is an important prerequisite for their consistency.

The obvious complementarity of the two approaches by Weaver and Bunge may suggest that both of them refer to each other. Considering Bunge, however, we do not find any explicit reference to the literature on complexity, despite the fact that he uses the term *complex* various times when describing the systems he has in mind. But there is no hint that he gives it a particular meaning. Weaver, on the other hand, does not seem to be interested in the particular ontological

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<sup>12</sup>Such kind of non-equilibrium models are very promising in explaining how empirical regularities such as Zipf's law could have emerged - in sharp contrast to models relying on standard equilibrium approaches, as is now acknowledged even by more conventional economists (Fujita et al., 1999). But this is a methodological question to be discussed in section 1.4.



foundations of his classification at all, probably because he did not consider social systems explicitly (although he mentions some examples for organized complexity that come from the social sciences).

One may now be tempted to use our definition of complex economic systems to scrutinize the general relevance of the complexity approach to economics: are the systems we observe in the real world complex in the sense it is used here? If they were not, the rest of this work would be useless, as would be the many promising research projects on economic complexity. But we are not yet equipped with the adequate toolset to answer this question: If economic systems in the real world are indeed complex, then we must ask the question of how we can understand them. Only if we know how to understand them, we can finally claim that they may or may not be existent, and, if they exist, study their functioning. This is why any framework for the study of complex economic systems must supply an adequate *epistemology* of complex economic systems. Again, I argue for a liaison of literature coming from the complexity sciences and social theory to build such an epistemology.

### **1.3 Epistemology: How to derive knowledge on complex economic systems**

The reciprocal relationship of epistemology and science is of noteworthy kind. They are dependent upon each other. Epistemology without contact with science becomes an empty scheme. Science without epistemology is - insofar as it is thinkable at all - primitive and muddled. Einstein (1949, p. 683-684)

Currently, there are only few explicit epistemological treatments of complex systems. This is why I spent considerable effort both in this thesis (chapters 3, 4, and 5) to develop an epistemology that is based on and consistent with the ontological concept of complex economic systems elaborated above.<sup>13</sup> At this point, I will provide an overview over this concept and extend it further because it is a key element of the framework constituted by the following chapters. The epistemology I propose draws on four main sources of inspiration:

Firstly, the concept of Bunge's systemism as introduced above serves as a good starting point, although I focus on a different aspect than in the preceding section. Secondly, institutionalist economic theory is necessary to correct a certain incompleteness and naïveté of systemism when it comes to economic systems.<sup>14</sup> Thirdly, the concept of generative social sciences as proposed by Joshua Epstein and Axtell (1996) and J. Epstein (1999) does provide some insightful arguments from the perspective of a complexity scholar. And finally, work based on epistemological

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<sup>13</sup>I also have another paper dealing with this topic that is not part of this dissertation thesis. In Gräbner (2015c) I develop the framework in more depth and use it to compare macroeconomic modeling using ACE and DSGE models.

<sup>14</sup>Beyond its contribution to this meta-theoretical framework, institutionalism can play an important role as a theory itself. I elaborate more on this in section 1.5.

contributions of the critical methodologist Uskali Mäki will prove useful when it comes to assess the epistemic content of particular models.

Taken together, a conjunction of these four sources will put the analysis of complex economic systems as defined above on sound epistemological footing and pave the way for a fertile methodological discussion of the adequate tools, both in the chapters that follow and in section 1.4.

### 1.3.1 The need for mechanism-based explanations

As anticipated above, for Bunge, the concepts of *systems* and *mechanisms* are inextricably related: mechanisms are an essential aspect of any system. For the full understanding of a system, it is therefore indispensable to identify its relevant mechanisms. This means that in the end any explanation of social phenomena must be mechanism-based, or *mechanismic* (Bunge, 2004, p. 188).<sup>15</sup>

A mechanismic explanation is not primarily aimed at generating particularly adequate predictions (although good mechanism-based theories often generate good predictions). It mainly aims at identifying the particular social or cognitive mechanisms operating in the real world and having brought about its *status quo*.

In doing this, mechanismic explanations go beyond a purely descriptive analysis that provides a very detailed exposition of the particular events leading from one situation to another. Instead of being focused on particular case studies, mechanism-based explanations are theories of medium-range: they do not constitute universal laws, but do have a certain generality (Hedström & Swedberg, 2005). The generality stems from the fact that the identified mechanism is an essential or accidental part of the system under investigation, and different instances of this mechanism can operate within the system. Also, as we will see below, a mechanism can be (accidentally or essentially) associated with different systems. But before elaborating on this matter further, a more precise definition of a mechanism is required.

Schelling (2005, p. 33) defines a mechanism as a “a plausible hypothesis, or a set of plausible hypotheses, that could be the explanation of some social phenomenon, the explanation being in terms of interactions among individuals or between individuals and some aggregate”. As mechanisms are to be considered “sequences of states within a given system” (Bunge, 2004), the “explanation” mentioned by Schelling means the identification of such a sequence.<sup>16</sup> This again shows that a mechanism-based explanation goes beyond a pure description of what can be

<sup>15</sup>Although the concept of mechanismic explanation is a key element of systemism as advocated by Bunge, it originates from a broader movement in the social sciences that originally comes from analytic sociology (Hedström & Swedberg, 2005), but that is also advocated by economists such as Schelling (2005).

<sup>16</sup>This definition is sufficient for the present purpose. But there is considerable literature on what is meant by a social mechanism. Particularly insightful is the overview in Hedström and Swedberg (2005), and the discussion of Bunge (2004) who explains why the two concepts of *mechanisms* and *systems* are inextricably linked, but nevertheless distinct: one must not conflate the categories of a *being* (in our case: a *system*), and the change of this being.

observed (what institutionalists such as Wilber and Harrison (1978) claim to be the institutionalist method<sup>17</sup>), but is in line with what many of the (truly) classical institutionalists advocated: Gunnar Myrdal, for example, developed several fairly general mechanisms, such as *backwash* and *spread effects* (Myrdal, 1973) or *circular cumulative causation* (Myrdal, 1944; Berger & Elsner, 2007). Thorstein Veblen not only started theorizing about the instrumental-ceremonial dichotomy of institutions (Veblen, [1899]2009), but also worked on several behavioral dispositions (or instincts as he calls them) that are explanatory for individual behavior (e.g. the instinct of workmanship (Veblen, 1898a)) or entrepreneurial motivations (e.g. the concept of *sabotage* (Veblen, 1921)).<sup>18</sup> All these mechanisms are (essentially or accidentally) associated with very different economic systems.

But why would one advocate mechanistic explanations in the first place? Similar to institutionalists (Wilber & Harrison, 1978), Hedström and Swedberg (2005) motivated the concept of mechanistic explanation as an alternative to the conventional *covering law model of explanation* (which dates back to Hempel and Oppenheim (1948)).<sup>19</sup> They argue in particular that the specific application of a law to a particular situation, as it is the usual practice prescribed by the covering law model, does not provide more information than what is already contained in the law. It does therefore not explain why the law should hold under these particular circumstances or not (von Wright, 1971). To state, for example, that Mr. Johnson will eventually die because he is a human, and all humans are mortal, is not a very illuminating explanation (Bunge, 1997, p. 412). There is nothing in the covering law model that requires one to specify clearly the link from the *explanans* (the general law and the initial conditions) and the *explanandum*.<sup>20</sup> Mechanism-based explanation, on the other hand, addresses this drawback by explicitly encouraging such an in-depth investigation by giving priority to explanations that provide as much information about the underlying sequence of causal links as possible.<sup>21</sup> But it would be desirable to have a justification for the approach ‘from first principles’, i.e. without referring to the disadvantages of alternative modes of explanation. Such a justification should be derived directly from the ontology on

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<sup>17</sup>This is a conclusion of the requirements they formulate before. I have no disagreement with the requirements they develop. To the contrary, they provide a encouraging starting point for social research. But at the time the paper was written, the tools I advocate to study social systems were not yet available.

<sup>18</sup>In chapter 4 I elaborate in more detail why I do think that these concepts must be considered as mechanisms, despite the fact that some institutionalists claim otherwise.

<sup>19</sup>According to the covering law model, to explain an observed phenomenon *E* means to deduce it as the logical consequence of the application of certain laws  $L_1, \dots$  on particular initial conditions  $C_1, \dots$ . Its canonical logical

form is thus given by  $\frac{L_1 \quad L_2}{C_1 \quad C_2} \rightarrow E$ . One particular feature of the covering law model is therefore the logical (and practical) equivalence of *explanation* and *prediction*.

<sup>20</sup>I will not provide a full-fledged critique of the covering law model here. This has been accomplished elsewhere, see e.g. Wilber and Harrison (1978), O’Shaughnessy (1992), or Bunge (1997).

<sup>21</sup>Furthermore, as elaborated in chapters 2 and 3, the mapping of functions (i.e. means to achieve a given aim) to mechanisms (i.e. a description of how things work) is one to many. consequently, arguing with outcomes is not sufficient any more. To judge the plausibility of a given theory, an assessment must not focus on the results of the theory alone. It must also refer to the model assumptions and the concrete mechanisms considered in the theory.

which the epistemology is going to be built: in our case, the *being* under investigation is an economic system. As it has been defined above, such a system consists of parts (or subsystems), their relations, and mechanisms associated with the system. Identifying these mechanisms therefore tells us something about the most fundamental nature of the object we are investigating. This is scientifically appealing because one investigates the essential core of one's subject directly.

Note that the dictum of mechanistic explanation does not commit the epistemological fallacy of *a priori* and *ad hoc* excluding potential explanatory mechanisms. In particular, it does not exclude effects operating from higher ontological levels on lower ontological levels, i.e. top-down effects.<sup>22</sup> There is no *a priori* reason to assume that sub-systems can affect their corresponding super-systems, but not the other way around. A canonical example from economic theory where exactly this is happening is an institution: it both depends on the behavior of individuals, but it also affects the behavior of individuals (see chapter 4 for multiple practical examples).

But the concept of mechanistic explanation is attractive for yet another reason: it provides a straightforward measure to choose between different models that explain the same phenomenon in a different way. This is a great asset compared to most conventional approaches: within a widely shared (implicit or explicit) instrumentalism,<sup>23</sup> the dubious concept of *Occam's razor* is usually put forward as the standard measure to distinguish between similar theories: according to the razor, if two theories explain the same phenomenon equally well, the simpler one is to be preferred. But there are two fundamental problems: Firstly, it is very difficult to measure the simplicity of a particular explanation.<sup>24</sup> Secondly, it is by far not clear when two theories explain the same phenomena *equally well*.<sup>25</sup>

In economics, the resulting strive for 'simplicity' (however defined) has led to a severe bias towards overly *simplistic* and unrealistic theories. One symptom of this is the abundance of assumptions that are made for *convenience* or to make a model more *tractable*. This practice has led to a situation where many essential features of the systems studied by economists are now absent from the majority of their models (a fact that becomes even more obvious and intuitive if

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<sup>22</sup>A naive form of methodological individualism, as advocated by many economists working in the context of rational choice, commits this epistemological fallacy (the so called *hierarchical fallacy*, see chapter 3 for a concise discussion).

<sup>23</sup>Instrumentalists claim that reality can only be understood through using models (a claim that I share), no matter how realistic the assumptions of these models are (a claim I do not share). Instrumental models usually focus on prediction and are often embedded into a positivist concept of scientific reasoning. The most famous example in economics is probably Friedman (1953), whose form of theorizing has come under serious critique (e.g. Musgrave (1981), among many others). See the edited volume of Mäki (2009c) for extensive discussions on this issue.

<sup>24</sup>For an extensive discussion of this subject see already Bunge (1961). This is one of the very few occasions where Bunge writes about issues of *complexity*, but in a very different meaning than we use it in this thesis.

<sup>25</sup>This is particularly the case if two explanations come from different, potentially *incommensurable* paradigms (Kuhn, 1962). As economics can currently be considered a multi-paradigmatic science (Elsner, 1986), this is a probable coincidence. I argue below that a comparison of different explanations is nevertheless possible, at least to some extent, if one accepts the discrimination method of the *deepness* of theories.

one uses the epistemological device developed below in section 1.3.4.).<sup>26</sup>

Within the approach of mechanistic explanations, an attractive and more precise alternative to Occam's razor is available: not simpler theories should be preferred, but *deeper* theories. One theory is deeper than another if it explains observed phenomena with recourse to more of the underlying mechanisms. Consider the following example: why does a rise in *real* per-capita income lead to increased per capita consumption expenditure? This is a central question if one wishes to understand the sustainability of growth rates.

Now consider two possible theoretical explanations for this observed pattern: The first one is a classical approach that assumes agents maximizing their utility for given preference relation which, among others, must fulfill the axiom of local non-satiation. This assumption is necessary if the results of classical demand theory should hold (Mas-Colell, Whinston, & Green, 1995). Starting from these assumptions there is a number of results that derive the empirical consumption patterns as an equilibrium solution. In particular, a changing proportion of goods consumed if the real income rises can be introduced by considering substitution effects due to the inferiority and superiority of goods, the latter being part of the preference relation assumed in the beginning. A considerable number of results could be obtained using this kind of approach (e.g. Dixit and Stiglitz (1977), Wadman (2000)).

However, as Witt (2001) points out, these studies do not explain where the assumed preference relations come from, and how they may change over time. In the strict sense, the majority of the explanatory content of these studies comes from the assumption of local non-satiation (Witt, 2001, p. 24). But where does this assumption come from, despite being a 'standard assumption of microeconomic theory' (Mas-Colell et al., 1995)? As argued by Witt (2001, 2010), consumption always serves the satisfaction of certain needs and wants.

These needs and wants can be either physiologically determined and thus homeostatic (e.g. for the need to collect food and shelter), or they can be non-physiological and non-homeostatic (e.g. for the want for group conformity or status seeking).

Witt goes on to propose an explanation on the grounds of his *continuity hypotheses* according to which the origins of preferences are to be explained rather than being assumed. He refers to the limited cognitive resources of human beings and the need for social cognitive learning which is then the vantage point for the social construction of symbolic commodity characteristics. Because of these symbolic properties, which are the results of a social coordination process, some products become capable of serving the individual need for social status. As a consequence, the demand for these (often rather expensive) goods rises.<sup>27</sup>

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<sup>26</sup>This potential danger of Occam's razor was already explicated by Galileo Galilei in 1632, and, later for the case of economics, by Carl Menger, who warned that "it is vain to do with fewer what requires more" (Menger, 1960, 4, p. 415). Today, more and more scientists (in physics, chemistry, and the life sciences) therefore are either very critical of, or reject Occam's razor as a critical principle for science altogether. See in particular the extensive qualitative survey of Riesch (2010).

<sup>27</sup>This is a very reduced form of the overall argument. Refer to Witt (2001) and Witt (2010) for a fuller description and a formal model.

Of course, the first type of model is much simpler than the second one, and all reach the same result. But the model by Witt (2001, 2010) considers the mechanisms underlying the formation of the preference structure. In the classical case they are simply assumed making the explanation *ad hoc*. Witt's model therefore ultimately leads to a much deeper and more illuminating explanation of the changing consumption in times of economic growth. Thus, this second type of model should clearly be preferred. Using Occam's razor as an alternative discrimination device would be less clear: while the first type of model is 'simpler' and both approaches come to the same conclusions, one may be tempted to use Occam's razor to support the first one. Defenders of Occam's razor could then argue that the second theory explains the observed facts better than the first one, but then they would lack a concept giving substance to this judgment.<sup>28</sup>

While I would argue that the idea of mechanistic explanation is of general importance for all social sciences, it is of particular relevance if the systems we consider are complex: according to the ontological definition from section 1.2.3, complex systems must be expected to carry a number of different mechanisms. These mechanisms may interfere with each other from time to time and important interaction effects among them may play an important role. It would therefore be advantageous to develop a certain toolbox of mechanisms, then to consider the particular situation at hand and identify which particular mechanisms are likely to be at work, and finally to consider these mechanisms plus their interaction effects: there is no *a priori* reason that mechanisms operate similarly in isolation and in conjunction with other mechanisms (S. Page, 2012).<sup>29</sup> An approach not focusing on mechanisms, in particular instrumental approaches, are likely to overlook these peculiar difficulties and will therefore run into trouble if they consider 'new' (or 'out of sample') situations (see for example Gigerenzer (2015) for numerous illustrations of problems arising if mechanisms operating on the individual level are not adequately considered).

But the idea of mechanistic explanations also comes up with a number of difficulties: firstly, to identify a particular mechanism in practice is difficult. This difficulty has a theoretical and a methodological aspect. The two aspects are discussed below in sections 1.3 and 1.4 respectively. Secondly, ambiguity can enter through confusion about what is meant by a social mechanism: Cowen (2005) for example argues that (neoclassical) economics is very successful in providing mechanistic explanations by showing how the market mechanism brings about a certain result.

It is of course very misleading to characterize the *market* as one particular mechanism (a widespread belief among economists from different persuasions, see already von Mises (1949) who considers the market as a particular process.)<sup>30</sup> Institutionalists have argued for a very long

<sup>28</sup>The idea of mechanistic explanation is a common topic in all chapters that follow and is most specifically discussed in chapter 3 (for the case of aggregation and dis-aggregation mechanisms) and 4.

<sup>29</sup>Note that we are still at an epistemological level. This is what would be desirable. But finding adequate methods that assist the researcher with this task is difficult, but not impossible, as will become clear from the methodological elaborations in the next section.

<sup>30</sup>Furthermore, Cowen's definition of social mechanisms as "rational-choice accounts of how a specified combination of preferences and constraints can give rise to more complex social outcomes" (Cowen, 2005, p. 125) seems to be more than questionable as it certainly conflates an ontological question (i.e. what a social mechanism is) with

time that markets are institutions and can function in very different ways, i.e. can represent very different mechanisms.<sup>31</sup> Furthermore, there are certainly social mechanisms that cannot be classified as a ‘market-mechanism’, even in a very broad sense, but that are nevertheless economically relevant - the evolution of preferences and social norms are only two examples. But such examples show that the concept of systemism was not initially designed to serve as a basis for economic theory. It is therefore to be complemented by institutionalist theory which can facilitate the search for and identification of particular explanatory mechanisms in economic systems.

### 1.3.2 Institutional contributions

When it comes to epistemology, institutionalists have always been a very sensitive research community. Much research effort was spent on building a well-reflected epistemology of institutionalist analysis (Elsner, 2012). In chapter 4 I elaborate extensively on two classical institutionalist papers, Wilber and Harrison (1978) and Myrdal (1978), that, despite their early publication date, are still very representative of the way institutionalists think about studying economic systems. Because formal models always require certain idealizing assumptions, and institutionalists are very eager to provide as realistic investigations of real systems as possible, they usually reject making the assumptions necessary for formal models, and instead advocate a certain way of verbal *storytelling* which they call *pattern modeling* (Wilber & Harrison, 1978; Tool, 2007) and which today is also known under the label of an *embedding narrative* (Elsner, 2015). I argue in chapters 2, 4, and 5 that this *methodological* conclusion of rejecting formal modeling *per se* is wrong: it is indeed possible to develop formal models in a realist tradition which foster our understanding of the real world. But the epistemology underlying their argument is very illuminating and shares with the preceding section the focus on mechanisms as the fundamental essence of explanation (although the authors do not state this explicitly). In addition, Wilber and Harrison (1978) and Myrdal (1978) formulate several requirements that institutionalist analysis must meet if it is considered to have epistemic content. These demands include a holist and systemist perspective. I show in chapter 4 that in fact modern systemism describes very well what was meant and that the terms of holism and systemism as used by them are now outdated. I therefore claim that a very natural relation between systemism and institutionalism exists (see chapter 2).

This relation is mutually beneficial: systemism provides a clear theoretical meta-language and well elaborated philosophical concepts and categories which can structure institutionalist theory and under which institutionalist concepts can be subsumed. Institutionalists provide

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a methodological question (i.e. whether social mechanisms can be studied using rational choice theory).

<sup>31</sup>The definition of a market itself is not straightforward at all. Not only has the term been used for so many things that it has lost much of its initial explanatory appeal, its definition also depends on other concepts, in particular those of ownership and contract. Building on this insight, Hodgson (2015) makes a nice proposal by defining a market as *organized and institutionalized recurrent exchange* (p. 139). Because of the indeterminacy of the term, it may be even better to avoid it entirely and instead describe the exchange mechanisms one has in mind more directly.

concepts that are more applied and add economic content to the systemist concepts.<sup>32</sup> In particular, the institutionalist epistemology does not remain on a meta-theoretical level but provides concrete *topoi* that help the researcher to identify the essential mechanisms: examples include the consideration of institutions and their underlying value base, as elaborated by Bush (1987) in his theory of institutional change, the considerations of power relations among members of different groups in society (Wilber & Harrison, 1978), the reflection of the epistemological implications of research tools such as game theory (Elsner (2012), see also chapter 5), the recourse on instinct-habit psychology as a starting point for the conceptualization of individual agency (James, 1890; Veblen, 1898b; Hodgson, 2004) and assumptions that are consistent with the insights of anthropology and evolutionary biology Witt (2004), Richerson and Boyd (2005), Cordes (2006), Witt and Schwesinger (2013)<sup>33</sup>. The latter was termed the ‘principle of evolutionary explanation’ (Hodgson, 2004), and is a very nice illustration of how the provision of these particular *topoi* helps to identify particular mechanisms and elaborate mechanistic explanations: it both gives hints at where particular mechanisms can be found, and represents a test whether conjectured mechanisms are really explanatory.<sup>34</sup>

Consider the example of explaining the dynamics of consumption patterns in times of economic growth again:

Explanations similar to that of Witt (2001) were already anticipated by evolutionary-institutional economists such as Veblen ([1899]2009), whose recourse on the instinct-habit psychology in the tradition of William James (in particular (James, 1890)) and William McDougall (e.g. McDougall (1908)) allowed him to identify certain instincts of humans that help explaining their behavior. His consideration of such particular psychological mechanisms led to the elaboration of particular social mechanisms such as *invidious distinction* and its corollaries including *conspicuous consumption* and *trickle down effects*. These provide plausible explanations for the increased consumption of ever more expensive luxury goods without using the doubtful formal maximization and equilibrium framework of neoclassical economics (Veblen, [1899]2009). In this case, his implicit practice of the principle of evolutionary explanation (see above) made him reject the premature results of neoclassical theory, and motivated to search for *deeper* explanations. It also suggested where these explanations could be located, i.e. in the evolutionary processes underlying preference formation. With his work, he thus paved the way for even more

<sup>32</sup>In this sense, institutionalist theory fulfills the task of a particular *theory* in Ostrom’s distinction between *frameworks*, *theories*, and *models*, which is an essential part of the methodological discussion in chapter 5. Note, however, that the philosophical framework elaborated here is even one level of abstraction above the concept of a *framework* in Ostrom’s taxonomy. I clarify this more precisely in section 1.6.

<sup>33</sup>I elaborate on the relationship between original institutionalism and modern evolutionary economics, to which the latter authors should be counted, in chapter 4. While the two schools have somehow departed, they share the same roots and, hopefully, will move closer together as part of the greater movement of complexity economics.

<sup>34</sup>It is also an example of how close the relation between ontology and epistemology is: the contributions of evolutionary economists and psychologists often deal both with the *being* of humans and their nature, and how *knowledge* about this being can be gathered. In the context of complexity economics the role played by these contributions is mainly epistemological as they provide *topoi* of how a complex economic system can be studied, not what exactly makes the system complex in the first place.



deeper explanations that consider recent advantages in evolutionary biology, psychology, and anthropology, of which Witt (2001) is one particular illuminating example.

### 1.3.3 The criterion of generative sufficiency

As became clear from the preceding section, it is desirable to have clear criteria for the kind of mechanisms that one accepts for explanatory purposes. I therefore add a further refinement to our epistemological framework for the analysis of complex economic systems: Joshua Epstein and Axtell (1996) and J. Epstein (1999) developed the idea of *generative social science*, an approach to modeling that has similar epistemological implications as the systemist concept of mechanistic explanations.<sup>35</sup> Unlike systemism, the idea of *generative social sciences* originated from a methodological, rather than epistemological debate and remains incomplete concerning the ontological and epistemological justification of its viable claims. However, it complements the concept of mechanistic explanation with the important criterion of *generative sufficiency*:

According to the dictum of generative sufficiency, any explanation in the context of the social sciences (including economics) must include a procedure of how the *explanandum* is generated by the interaction of the parts in the system under investigation.<sup>36</sup> As we will see in section 1.4, this claim is very different to what is currently practiced in most of the social sciences and involves non-trivial methodological consequences: The equilibrium mode of explanation, for example, is not necessarily compatible with the epistemological requirement of generative explanation. Currently, explanation often means showing that what is to be explained is the equilibrium outcome of an interaction among different rational players. But despite the fact that this often requires unrealistic assumptions concerning the computational capacities of individual agents, many equilibria in a neoclassical or game theoretic context are simply not attainable, even for fully rational agents. Take as an example the model by J. M. Epstein and Hammond (2002), where the authors study a very simple game of spatial dynamics where almost all analytic equilibria cannot be reached by rational agents. Such a model would not be explanatory in the generativist sense.

The requirement of generative sufficiency is useful because the systems we observe in reality *have been* generated by certain mechanisms. So if we consider our claim as identifying these mechanisms, then the test of whether the proposed mechanisms are able to generate what we observe in reality is helpful: it excludes potentially misleading explanations and reduces the set of candidate mechanisms and explanations.<sup>37</sup> Further, if one wishes to develop policy advice,

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<sup>35</sup>But they are not the first ones who argued in this direction. A very similar statement can already be found in v. Hayek (1945).

<sup>36</sup>Note that this claim already requires a notion of a system and implicitly assumes that systems must be made of interconnected parts. The criterion of generative sufficiency is thus obviously compatible with our ontology of complex economic systems developed above.

<sup>37</sup>In particular, several mechanisms can bring about the same result in reality, so every method to discriminate among candidate explanations is highly welcome. I discuss this issue in more depth in chapter 3.

one has to ensure that the suggested measures are actually able to *generate* the desired outcome. In some respect, the criterion of generative sufficiency goes beyond the dictum of mechanistic explanation (because not all mechanisms we can think of are computable and thus potentially generated by the interaction of individual agents).

But in other instances, the principle of mechanistic explanation is more demanding than the generativist approach: Darley and Latané (1968), for example, discovered the so called *Bystander-Effect* according to which people start being reluctant to help others in distress if the number of bystanders increases. Their underlying idea was that interpreting social situations is extremely demanding for the human brain. Humans therefore developed heuristics to decrease the computational burden. To explain the particular cognitive processes underlying the decision to help someone in distress, Latané and Darley (1970) developed a five-level model of human decision making that includes noticing that something is happening, interpreting the event as an emergency, taking responsibility for providing help, and deciding to help. The last two steps are important here: to decrease the computational costs of decision making, humans try to orient their behavior on others who can be expected to have made a (costly and reflected) decision themselves. This kind of behavior is therefore likely to be the result of an evolutionary process of heuristic formation.

If this is to be implemented in a generativist model as advocated by Epstein, one would program agents that make their decision to help as a probabilistic function of those who observe the event without providing help. If this leads to the observed behavior (i.e. that people are more likely not to help others if there are more bystanders), then this would meet the criterion of generative sufficiency. But it does not provide as much insight into the system under study as the claim of Latané and Darley (1970) which adds two important aspects to the explanation: firstly, the authors claim *that* the cognitive processes underlying the decision to help others involve the functional relationship between the probability to help and the number of bystanders. Secondly, the psychologists explain *why* people have developed such cognitive processes involving a majority rule. The resulting explanation thus provides an even *deeper* explanation than simply putting the majority rule into the code for the individuals of a computer simulation, which could also be a simple *ad hoc* decision. Of course there is nothing wrong in building such a simulation if the implementation of the majority rule is justified by psychological evidence - but then we move beyond what is demanded by the generative dictum: the true explanatory value added comes from the recourse to the additional mechanism.

### **1.3.4 How to identify social mechanisms? Building models as surrogate systems**

So far I have argued that an understanding of complex economies comes from the identification of particular economic mechanisms that meet the criterion of generative sufficiency..

What remains open is what the identification process can look like - both in theory and in

practice. The latter is a question of methodology and is taken up in section 1.4. The former is a matter of epistemology and is discussed in the following. I will argue that the only *conceivable* way of identifying mechanisms in the social sciences is to build models that help to *isolate* the effect of particular mechanisms.

By nature, a model is an abstract and thus coarse-grained picture of reality. This is inevitable: even if one does not confine oneself to any formal modeling framework and describes the system under investigation with pure words, one will never be able describe it completely.<sup>38</sup> For example, if one wishes to explain the industrial dynamics of the IT sector in Germany, then there is no need to describe the exact composition of the workforce of every single company. While this would make the model more realistic, it would not help in illustrating the industrial dynamics.

Usually the answer of which details to include in a model is less easy to be found and the epistemological question of how we can learn from models whose assumptions are, at least partly, ‘false’, is important: Building upon the work of Uskali Mäki and the following chapters of this thesis, I develop an epistemological framework that illustrates the way we learn from models and that helps to wrap up what has been said about social mechanisms. It is built upon Mäki’s concept of “models as *isolations* and surrogate systems” (MISS, Mäki (2009a, 2009b)) and it highlights the essential part of modeling: to isolate the important from the unimportant. In our case it will be used to isolate social mechanisms and their interaction effects:

In the MISS approach models are considered to have two fundamental aspects. First, they *represent* the real world. As reality is too complex to be understood directly, we need to reduce its complexity by abstracting from details, thus building a coarse-grained picture of reality. Here we make the important distinction between *surrogate* models and *substitute* models (Mäki, 2009a): A *surrogate* model results from an active and reasonable attempt to learn something about reality and is therefore a direct representation of the real world situations under study. In contrast, we speak of a *substitute* model if the act of representing reality was a failure, either because the researchers did not accomplish their goal (e.g. by choosing a wrong form of representation and by missing the essentials of the system under investigation) or because they simply want to study the model for its own sake. At this point, it becomes clear that it is important to have at least a rough ontology underlying the model building because it gives important clues about what should be included in the model: it is the set of *essential* features of the system under investigation that deserves particular attention.

The second aspect of a model is that of *resemblance*. If reality is observed at two successive points of time, its state has changed. The underlying mechanisms are, for reasons of complexity, often not directly understandable. One therefore studies the model one has built as a representation of reality. If the state of the model is recorded at two points of time, it has changed due

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<sup>38</sup>To some extent the division into verbal and formal models is artificial: not only do both reduce the complexity of their target system, both use a certain grammar system to structure their description. Nevertheless, they often represent different approaches to modeling concerning the degree of abstraction that one wishes to obtain.

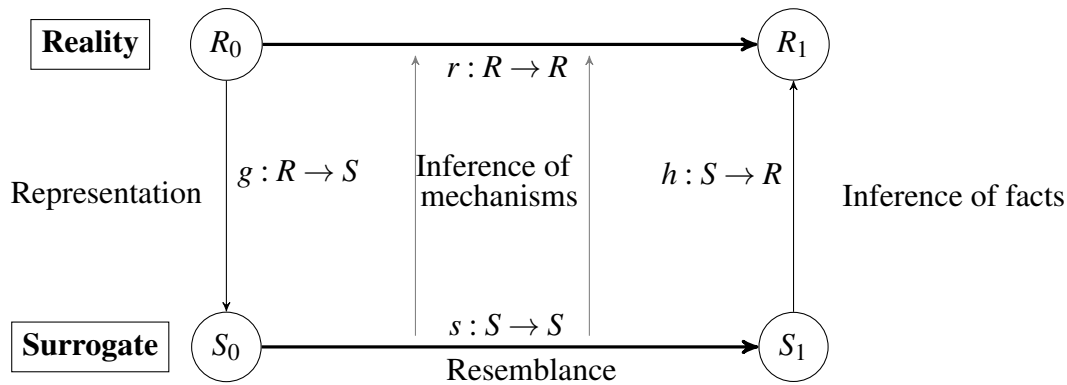


Figure 1.3: A development of Mäki's MISS concept, where I interpret modeling as a mapping process (following Miller and Page (2007)) and distinguish between the inference of mechanisms and facts. The figure is taken from Gräbner (2015c).

to the mechanisms built into the model. Studying the behavior of the model (e.g. by altering certain parameters or by implementing different functions) is called *model exploration*. If we can learn something about the real world by the exploration of our model, the model resembles the real world. Here, the act of 'understanding reality' can be interpreted in different ways, but we already elaborated on what this *understanding* means for us: to identify the particular generative mechanisms operating in reality.

Figure 1.3 illustrates the fundamental idea of the MISS approach. The modeler builds a surrogate  $S_t$  of reality  $R_t$  at time  $t = 0$ , which is of lower complexity than reality itself. This process can be thought of as a mapping  $g$  from reality to the model. The processes that drive the dynamics of the model can be thought of as a mapping  $s$ , and the processes that drive the dynamics of reality can be thought of as a mapping  $r$ . After the model world has evolved from  $S_0$  to  $S_1$  at time  $t = 1$ , one can then compare the resulting system  $S_1$  with reality  $R_1$  via the mapping  $h$  (i.e. comparing the resulting 'facts'). Or, one may assess the plausibility of the mechanisms operating in the model compared with reality, which may or may not lead to a similarity between  $R_1$  and  $S_1$ .

Figure 1.3 summarizes the approach and clarifies why a sole focus on predicting the right variables is not sufficient to guarantee a model's usefulness for understanding the mechanisms operating in the real world. One may either infer facts correctly without having used adequate mechanisms in the model (a common drawback of purely instrumental models) or make incorrect predictions even if one has implemented the right mechanisms. Consider, for example, chaotic systems. Here one knows that an exact prediction is impossible precisely because one knows the mechanisms governing the dynamics of the system. A more practical example is the evolution of technology. In Arthur (1989), a model of technology choice, it is impossible to predict *ex ante* which technology will be the dominant one (or even if a single technology becomes dominant), but the behavior of the model is nevertheless very well understood.

### 1.3.5 Summary: an epistemological foundation for the analysis of complex economies

The sound ontological definition of complex economies from section 1.2 allowed us to develop a corresponding epistemological framework for the analysis of such economies. The parts of this framework come from analytical sociology and Bunge's systemism, enriched by the epistemological awareness and the economic *topoi* of original institutionalist economic theory, the criterion of generative sufficiency, and the epistemological device developed based on Mäki (2009a, 2009b).<sup>39</sup> All of the four parts are important. We end up with a research strategy that aims at identifying social mechanisms that are potential (and probable) drivers of what we can observe in the real world and that makes explicit use of models that isolate both the effects of single mechanisms and the relation between different mechanisms. Hereby, we favor models that are particular *deep* in the sense that they refer to as many explanatory mechanisms as possible without conflating their particular effects. In such sort of framework, there is a natural incentive to replace assumptions made for convenience with those that can be justified with recourse to plausible mechanisms.

The final step that remains in building a full-fledged framework for the analysis of complex economies is an adequate methodology: what are suitable and promising means to generate knowledge as it is suggested in this section?

## 1.4 Methodology: Complexity economics needs computational methods

The tool kit is not as important as the perspective, but it is imperative for giving the perspective meaning in any applied sense. Hayden (1982, p. 638)

Given our elaborations on the ontology and epistemology of complex economics systems, we now turn to the question with which tools these systems are to be analyzed. This question necessarily comes third after deciding *which* system to study (i.e. clarifying the underlying ontology) and *how* knowledge about such systems can be generated *in principle* (i.e. clarifying the corresponding epistemology).

While the choice of a particular research tool is not necessarily bound to a certain theoretical orientation, and tools and theory are certainly distinct from each other, there is an important relation between them: certain methods are incompatible with certain epistemological and ontological frameworks, so the decision for a particular modeling framework always entails certain epistemological and ontological statements (which is one of the main topics of chapter

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<sup>39</sup>I have further extended this device further to its current form and applied it to modern DSGE modeling in a paper that is not part of this thesis (Gräbner, 2015c).

5). But also within a certain epistemological and ontological framework, different methods are available and the choice can (and should) be made according to convenience and ease.

Throughout this section I will argue that there are, in principle, several different methods suitable for the study of complex economic systems. Some of them focus on abstract theorizing and theory-building (e.g. difference equations, replicator dynamics, or evolutionary game theory), others on the exploratory study of complex economic systems or hypothesis testing (e.g. statistical network analysis or machine learning). But there is one method that takes a special place among the tools used to study complex economic systems: firstly because this method is somehow in between purely theoretical and empirical methods and provides a very direct test of theoretical mechanisms against empirical data (see S.-H. Chen (2012) and chapter 5).

Secondly, because it serves as an ultimate plausibility check of whether the arguments brought forward by a certain theory are consistent with the ontological and epistemological framework developed above. This method is referred to as *agent based computational economics* (ACE).<sup>40</sup> Because of this distinctive status among the existing modeling tools I will focus on ACE modeling throughout this methodological section.

The fundamental idea of ACE models is to explain the dynamics of an economic system through the behavior of and the interactions among the fundamental entities of this system. These models are called *computational* because they derive the implications of their assumptions by the sequential application of a set of computations involving its entities.<sup>41</sup>

ACE models are a particular subset of computational models that accentuate both a flexible and more realistic conception of individual agents and allow studying the interplay between different ontological levels of the economy: despite their name, ACE models are not necessarily purely ‘agent-based’: causal processes in the models can go from the agents to meso and macro structure and *vice versa*. This makes them particularly suitable for the analysis of institutions, a point that is taken up again in the next section. Nevertheless, their main feature is the consideration of a large number of heterogeneous agents that interact directly with each other and with their environment - therefore the name *agent-based* is now widely accepted.

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<sup>40</sup>I provide a non-technical introduction in chapter 4.

<sup>41</sup>Note that not all computational models involve computer simulations: Schelling’s dynamic models of segregation, including the famous *checkerboard model* (Schelling, 1971), do not involve a computer simulation in the usual sense: Schelling used a piece of paper and colored coins to carry out his ‘computations’. Nevertheless, the logic of the model was computational (because his coins ‘moved’ according to a well-specified set of rules) and it can straightforwardly be implemented on a digital computer. In this respect it differs from the classical general equilibrium models: before Scarf (1973) developed his famous algorithm that used a particular simplex method to actually compute the equilibria of general equilibrium models, it was by no means clear that theoretical equilibria could be computed using real data in applied work (Arrow, 2005). The branch of applied microeconomics that resulted from Scarf’s work is called *computable general equilibrium modeling* and is still very different to the pure general equilibrium theory, which is not at all computational. But contrary to what is advocated in this thesis as mechanistic explanations, there is no intuitive interpretation for what the Scarf algorithm does: it uses an elaborated simplex method to find equilibria. But there is certainly no such mechanism operating in reality: even if there were mechanisms that push the economy towards an equilibrium, such mechanisms would not have to do anything with simplexes at all.

Technically, however, the name *object-based* would be more appropriate because most ACE models are written according to a programming paradigm called *object oriented programming*, where every artificial entity is an object. Note that an agent is an object, as is its environment and (depending on the design) an institution influencing its behavior, or even the society as a whole - the hierarchy between the different objects enters through the interpretation of the model. It is not prescribed by its technical design. The way to represent elements of the real world directly as objects in the model is a major demarcation point to many analytical equation based models. Although this is not a technical distinction, it illustrates a distinctive style that makes it easy to align models with the real world systems they should represent. On the other hand, this style makes it difficult to communicate the models within the scientific community and to align them with existing, analytical models.<sup>42</sup>

The rest of this section is about why ACE models are particularly useful for the study of complex economies: I will first show that ACE models conform to our conception of complex economic systems and that they are a viable tool for their analysis (section 1.4.1). I then go one step further and argue that ACE models are in fact indispensable for the study of complex economic systems (section 1.4.2). This, however, does not mean that there should be an *exclusive* focus on ACE models: these models have some important weaknesses discussed in section 1.4.3 that can only be addressed effectively if there is a certain pluralism of methods. Building on this observation, I argue that many alleged dichotomies of ACE models and alternative approaches are artificial. I illustrate this in section 1.4.4 by explaining that agent-based and equation-based modeling approaches are to be considered complements rather than substitutes, and in section 1.4.5 that ACE can and should be a useful bridge between theoretical and empirical analysis.

### **1.4.1 ACE models are consistent with the ontological and epistemological framework**

According to the previous elaborations on the ontology and epistemology of complex economies, an adequate method to study complex economic systems must meet the following general criteria:

1. From the ontological nature of complex economic systems it follows that an adequate method must be able to represent the system under investigation as a system of organized parts, or subsystems.
2. From this ontology it also follows that an adequate method must be able to represent mechanisms operating in these (sub)systems. In particular it has to account for a potential self-organization of the system, potential interaction effects among different mechanisms, and for both top-down and bottom-up effects.

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<sup>42</sup>Aligning models with each other is generally difficult. Axtell, Axelrod, Epstein, and Cohen (1996) developed a useful framework to align simulation models. As we have shown in Alvarez-Pereira et al. (2015), this works equally well for the case of simulation and non-simulation models.

3. My epistemology of complex systems requires a method that is capable of providing mechanistic and generative explanations for the phenomena under study. In this context, it must be able to potentially represent a wide range of mechanisms (going beyond pure market mechanisms).

I argue that ACE modeling meets all these criteria and is therefore a viable method to study complex economic systems. I have elaborated on related arguments in the context of how ACE models can be helpful for institutionalist theorizing in chapters 2, 4, and 5. These arguments equally apply in the current context. In the following I will therefore only extend these arguments in relation to our conception of complex economic systems where necessary:

**The representation of sub- and super-systems** Today ACE models are usually programmed according to the *object oriented programming paradigm*. This means the programs consist of *objects* and *methods* working on these objects. This allows one to represent entities in the real world as objects giving them a straightforward interpretation. Such a way of programming aligns perfectly well with the ontology suggested above: each system can be modeled as an object (more specifically: an instantiation of a *class*), and the mechanisms this system carries are the methods of this class. Subsystems of these systems can equally be modeled as classes and refer directly to the properties of their super-system. Note that this hierarchical structure of sub- and supersystems is not a technical necessity. It is reflected only in the causal relationship among the classes and only during the interpretation of the model this hierarchy becomes explicit. Technically, an *agent* is a class just as a *social institution* and their hierarchical relation is constituted in the *interpretation* we give to the two classes. The fact that emergence of e.g. a certain wealth distribution is considered an upward effect, and that the way people orient themselves on social institutions is considered a downward effect does not follow from the technical specification of the ACE model alone.

**The representation of mechanisms and their interactions** Mechanisms are implemented in ACE models as methods - a very clear programming concept. ACE models are also a natural way to represent many different parts of a system (e.g. agents, which may be represented as instances of an agent class) that are related to each other in an organized way (through the exogenously given or endogenously emerging network structure) and that lead to emergent properties of the system. Because the information of the agents is usually (but not necessarily) local, and the same is true for their interactions, ACE models are also predestined to represent *self-organizing* processes.<sup>43</sup>

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<sup>43</sup>This capability is of particular importance for many heterodox schools of thought that do not consider self-organization to be *a priori* beneficial: the consequences may well be devastating for the agents involved. In such cases, it is appropriate to think about how to control the self-organizing mechanisms. This is ultimately a question of studying the interaction effects of different mechanisms, a task that is very difficult to accomplish with non-computational tools.



**The isolation of mechanisms and mechanismic and generative explanations** More important than *representing* mechanisms is to isolate their effect on the economic system under study: most mechanisms in an ACE model are (or at least *should be*) accounted for in a *modular* way: this means that the modeler can turn them on and off and thus elaborate very explicitly on their *isolated* effect and the *interaction* among different mechanisms by studying their effect both in co-existence and absence of another mechanism. In Alvarez-Pereira et al. (2015), for example, we study the effect of different institutions of reproduction on the inequality dynamics of a particular society. In our model we can vary the degree of assortativity among different social classes and determine the effect on the timing on inequality dynamics. This allows us very well to isolate the precise effect of assortativity when it comes to marriage and reproductive institutions. Another example that also illustrates how both upward and downward effects can be implemented in a simple ACE is the model by Hodgson and Knudsen (2004). For more details I refer to the extensive discussion of the model in chapter 4. In this chapter I also give various examples of how mechanisms that have received particular attention in institutionalist theory can be accounted for in ACE models. Furthermore, explanations in terms of ACE models are also consistent with the requirement for generative explanations: In fact, the whole concept of *generative social sciences* comes from the agent-based simulation community (Joshua Epstein & Axtell, 1996; J. Epstein, 1999). ACE models are the prototype to deduce aggregate dynamics from the interaction among heterogeneous and interdependent agents.

### 1.4.2 Why ACE models are required for the study of complex economic systems

ACE models are not only a viable, but also an indispensable tool for an ultimate understanding of complex economic systems. There are three main reasons for this:

1. The essential mechanisms or composition of certain complex economic systems may be such that even the simplest adequate representation can be studied only through agent-based simulations.<sup>44</sup> One example is a two-sided market: here the nonlinear interaction among different microeconomic actors exceed any level that can be dealt with in analytical models and the decision making strategies of the agents are of such theoretical relevance that abstracting the micro level would signify an enormous loss of credibility for the model (Heinrich & Gräbner, 2015). See Furtado and Sakowski (2014) for an outline of various mechanisms that require the ACE framework to be represented adequately.
2. Even in the case where a surrogate model of the complex system under study is available without using the ACE framework, ACE models are usually the only modeling device that

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<sup>44</sup>Note the direct link to the epistemological device and the ontological definition elaborated above: a system consists of an organizational composition and it carries mechanisms. The essential properties of both of these aspects must be considered adequately during the complexity reduction process if an adequate surrogate model is to be developed.

allows for an effective study of the *interaction effects* among *different mechanisms*, which are, by definition, part of any complex economic system (see Alvarez-Pereira et al. (2015) and chapter 4).

3. ACE models provide the ultimate proof that the implemented mechanistic explanation meets the criterion of generative sufficiency. While there are in principle also other ways than direct computation to prove that the equilibria derived in an equilibrium model are in fact computable and stable, such methods are seldomly applied and not always available. See Velupillai (2000) for a greater exposition of the application of *constructive* mathematics in the context of *computable* economics. But these explanations often suffer from a lack of reference to real world mechanisms and thus regularly fail the requirement of mechanistic explanation.

These arguments neither mean to downgrade non-computational work in the context of social economic systems neither do they suggest an exclusive methodological focus on ACE: as we will see below, ACE models are not without problems. In particular, the resulting models are often complex and not easy to describe. They must therefore be built on very clear theory, which may well be provided by other kind of theorizing.<sup>45</sup>

### 1.4.3 Potential pitfalls of ACE models

There are a number of objections against ACE modeling. The most reasonable and common ones are discussed in considerable detail in chapter 4. Nevertheless, there are some drawbacks that deserve to be mentioned here because they substantiate my claim that while computational models are indispensable, one should not rely on them *exclusively*.

**Overfitting and too complex models** Most ACE models are simulation studies. Such models lack the pragmatic disciplining device of a solution concept based on equilibrium analysis which always provides a natural incentive to keep models as simple and illustrative as possible (a drawback simulation models share with many other approaches in economics, e.g. experimental economics (Miller & Page, 2007, p. 70)). Simulation studies are often complex and involve many lines of programming code. This entails both a pragmatic and a serious disadvantage: the pragmatic disadvantage is that a large part of the corresponding papers should be devoted to the description of the model and less on the discussion to the results.

The serious disadvantage of this is that isolation of mechanisms within these models may quickly become difficult and the exact functioning of the model is not clear any more. This is particularly discouraging if a mechanistic explanation is aspired: even if the model provided reasonable

<sup>45</sup>I have argued elsewhere that building ACE models out of well-defined equation based models is a fruitful way of research, which is why I consider the two approaches to be *complements* rather than *substitutes* (see also section 1.4.4). One example is Alvarez-Pereira et al. (2015).

predictions, as long as the mechanisms operating within the model are not clear, it does not meet the epistemological demands formulated in the preceding section.

Concerning the particular research practice pursued, it would therefore be desirable to first establish analytical proofs for further reduced version of one's model and then to move on to the more complicated computational models. In order to keep the latter as transparent as possible, the first aim of the computational model should always be the replication of the mathematical results obtained before. Such a strategy is a reasonable disciplining strategy to avoid overparametrization of the simulation model and ensures the identification of particular mechanisms and their mutual influences.<sup>46</sup> It also anticipates my claim that analytical and ACE models usually should be considered complements rather than substitutes (see Alvarez-Pereira et al. (2015) and section 1.4.4). However, such a strategy may not always be feasible: sometimes, even the simplest possible surrogate model is not subject to an analytical treatment, either because there are too many essential mechanisms and details in the system under consideration, or there are some particular features (e.g. true uncertainty or a particular learning behavior) that prohibit an analytical treatment. In such cases, only careful documentation, publication of the source code, and careful reference to comparable models can help.

**Confusing equifinality** One difficulty of the social sciences in general is the fact that *equifinality* is a common phenomenon: There is usually more than one particular mechanism that yields the same particular consequence.<sup>47</sup> In the context of the particular ACE models, this raises the concern of potentially arbitrary choices of mechanisms within the model: if one chooses to model the learning behavior of an agent, there are many different learning algorithms available (Brenner, 2006). And usually, there is not enough information available to make a theoretically well-grounded choice among the different algorithms. Then the only choice that remains is to test whether the consequences of using different algorithms are negligible. If this was not the case, the only viable strategy would be stating explicitly the relevance of the choice of the algorithm. But since models are usually built to illustrate the importance of mechanisms other than the particular learning algorithm of the agents itself, this procedure is unfortunately not very common. This can then lead to a certain intransparency concerning the results of ACE models as readers may not be sure about where exactly the results come from. Again, there is no other option than ensuring a premium on scientific honesty and to provide incentives that ensure the publication of the source code of published simulation papers. This would ensure that the results can be replicated and assessed by other researchers. Fortunately, this is more and more becoming a dominant practice for simulation models.<sup>48</sup>

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<sup>46</sup>For concrete examples in the literature see e.g. Miller and Page (2007), Bednar and Page (2007) or Hong and Page (2012).

<sup>47</sup>Or, in the words of chapter 2: "the function-mechanism relation is principally one-to-many, since different mechanisms can be used to achieve a specific aim." (Gräbner & Kapeller, 2015a, p. 435).

<sup>48</sup>See, for example, the webpage on 'OpenABM', where many published ACE models are freely available. Simulation journals such as JASSS explicitly require authors to publish their models on such outlets.

Note, however, that the problem is not specific to ACE modeling but also exists in applied micro and macroeconomics (in particular the most common modeling frameworks of *computable* and *dynamic stochastic general equilibrium models*, where the results may even depend upon the exact specification of the utility functions or the approximation algorithms used to solve the models (Heiberger, Klarl, & Maußner, 2015)) and econometrics (where multiple candidates for the estimation of inference method exist, data can be either included or excluded (e.g. Herndon, Ash, and Pollin (2014)), or *p value hacking* is used to ensure significant estimation results (Nuzzo, 2014)). And even in pure microeconomics, it is often not explicitly discussed why the particular form of utility function has been used.

**Difficulties of micro-calibration** The problem of difficult micro-calibration relates to the problem mentioned above: because ACE models are not confined to the model of a utility maximizing agent (or a profit-maximizing firm), an alternative decision making algorithm on the micro level of the model must be employed. But which one exactly is to be used is often a difficult question without an unambiguous answer since “there is only one way to be fully rational, but there are many ways to be less rational.” (Holland & Miller, 1991, 2, p. 367). This provides a certain room for arbitrary choices by the modeler, and requires again a confinement to transparent research and the publication of the simulation code to make the models reproducible and to actively test the theoretical consequences of different micro specifications.

But this potential weakness can also be turned into a strength if good theoretical justifications for the micro specifications exist. Some more sophisticated ACE models even take an experimental approach to exploit this potential: Here, humans take the position of the artificial agents and the latter are then calibrated to the behavior of real human beings.

And note that the *lack* of micro-calibration is a serious drawback of alternative modeling approaches such as *computable* or *dynamic stochastic general equilibrium* modeling: here, the results are rendered dubious because these models *cannot* be calibrated to match realistic behavior on the micro level and are forced to employ the (empirically more than questionable) rational utility maximizing agent.

**Communication of models and results** Mäki (2011) studies the different aspects of economic models and distinguishes between ontological and pragmatic constraints to economic modeling: ontological constraints originate from the ontological nature of the system under consideration and prohibit, for example, the use of a macroeconomic model to study microeconomic questions. Pragmatic constraints are set by the researcher and the scientific community: a model that has the aim to illustrate particular mechanisms should not be calibrated to yield optimal predictions. And a model that should be published in the, say, *Journal of Economic Issues* should at least discuss the relevance of the model to the respective research community.

In this sense, it is important that the language used to describe the model is understood and accepted by the desired audience of the model. Most economic models therefore use the language

of mathematical equations. Consequently, introducing models that are written (partly or entirely) in algorithms, or that defy the conventional maximizing-cum-equilibrium approach, is not always easy: usually, one requires more space to introduce even basic concepts, as most economists are still not very familiar with algorithmic models. From a technical or logical viewpoint, there is absolutely no difference between an algorithm or an equation (see Hodel (2013) and section 1.4.4), but the way the two strategies of building a model are perceived by the economic community are very different: the use of an algorithmic modeling style usually still warrants precise justification and the model description often already takes a large part of the respective research paper, leaving less space for the discussion of the actual results.<sup>49</sup> While this last point is pragmatic, rather than technical, it is still important since it affects the way ACE models are designed, presented, perceived, and interpreted.

#### 1.4.4 The symbiotic relationship of ACE and equation-based models

Unfortunately, methodological discussions about the adequacy of ACE modeling are often framed as decisions among mutually exclusive modeling paradigms that cannot be related to each other. For example, using an ACE model or an equation-based model (EBM) is frequently considered a mutually exclusive way of approaching a problem. But framing this decision in such a dichotomous way overstates both the theoretical and technical differences among the approaches.

From a technical perspective, ACE models consist of equations as do EBM consist of algorithms. Due to the Church-Turing thesis, every algorithm could equally be expressed as a recursive function and *vice versa* (Joshua Epstein, 2006; Hodel, 2013). And from a theoretical perspective, most ACE models involve aspects that are represented as equations. Though one may classify most models as either EBM or ACE models based on whether their fundamental aspects are expressed through equations or through algorithms. Nevertheless, a clear classification is not always feasible and a gray area between the two classes of the models does exist (see also Alvarez-Pereira et al. (2015)).

But even in the cases where a rough distinction between ACE models and EBM can be made, the two classes can be related to each other very productively.

The epistemological framework outlined in section 1.3 provides a straightforward justification to view a phenomenon *both* from an equation-based and an agent-based perspective. EBM are usually very exact in the process of model exploration. This is because all mechanisms are expressed via clear equations and verification can take the form of a rigorous proof (at least if the model is tractable). ACE models are often represented in an algorithmic form and must be simulated and a single simulation only represents one potential trajectory through the state space of the model.

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<sup>49</sup>In econometrics, usually less space is devoted to the actual estimation procedure. This is, however, entirely accepted by the economic community, as the tools are already considered standard.

On the other hand, the ability of EBMs to represent the real world is usually more restricted than that of ACE models: Due to tractability considerations, EBMs have fewer dimensions than ACE models and EBMs require a greater reduction of complexity. This means that they can be explored in fewer directions than ACE models. Also, there are particular mechanisms that are very difficult to represent in an EBM, such as learning (Furtado & Sakowski, 2014), true uncertainty (Pyka & Fagiolo, 2007), or the endogenous formation of preferences (Hodgson & Knudsen, 2004). The greater flexibility of ACE models makes them suitable devices to test for the importance of implicit assumptions made during the representation process in an EBM (Rahmandad 2008):

Consider the role of aggregation mechanisms as a practical example. ACE models can be used to explicitly study the aggregation mechanisms generating the macro observables of the system, or can take macro (or meso) variables themselves as fundamental starting points. EBMs often start with such macro observables and assume a certain aggregation mechanism as given (Parunak, Savit, & Riolo, 1998). By comparing the ACE model (where the aggregation mechanism is explicit) with the EBM (where the aggregation mechanism is implicit), one may examine whether consideration of the aggregation mechanism is needed. In the context of the epistemological framework from above, with an ACE model one can identify the situations in which the aggregation mechanism of an EBM is appropriate and whether the EBM is an adequate surrogate of the system under investigation (or whether the aggregation mechanism in the EBM is misleading and it should be considered an substitute model instead). As such, the ACE model can increase the explanatory meaning of its associated EBM.

The strengths and weaknesses of EBMs and ACE models are thus complementary and EBMs are often important in order to get a good intuition about the mechanisms of the system under investigation. In the end, however, to completely meet the demands for adequate modeling complex economic system, an agent-based version of the equation-based model is required (see section 1.4.2). But as already anticipated in section 1.4.3, in the process of developing such models, the development of good equation-based models may be an important step that effectively addresses potential over-fitting of ACE models.

### **1.4.5 ACE modeling and empirical research**

At the end of this section I comment on a too often unrecognized potential of ACE modeling: the systemic empirical evaluation of theories. If the required data is available, ACE models can evaluate theories on different ontological levels in one consistent model: they are subject to micro-, meso-, and macro-evaluation, and produce data on intermediate steps in the model, which may be mapped against real data (Rahmandad & Sterman, 2008). The fact that such an approach requires a lot of quantitative data is not a disadvantage compared to other empirical approaches.

One drawback of such a strategy is of course that one can only identify *possible* explanations for the observed data: if an ACE model replicates the observed macro and meso data with sufficient statistical precision, one can infer that the mechanisms of the ACE models are a *plausible explanation* for what has been observed in reality. But there can never be an ultimate answer to the question of whether it is *exactly this* set of mechanism. This is, of course, a problem for any form of scientific inquiry in the social sciences: even if one describes the system under investigation with a very detailed verbal exposition, one conducts a reduction of complexity of the original system and proposes mechanisms that are consistent with the data we possess about the system. The huge advantage of the ACE models is that they provide an environment to test for the consistency of various hypotheses concerning micro, macro, and meso level of the economy *simultaneously*.

A very similar research strategy has been taken by conventional macroeconomics with the DSGE approach which was initially meant to go beyond less theoretical time series analysis:<sup>50</sup> here the models contain a set of hypotheses about how the economy under study works, and then either the model parameters are calibrated to match the time series of interest (the so called *calibration approach*) or to estimate the free parameters of the model and then test whether the model replicates the empirical data (the so called *estimation approach*).

ACE models can be used in a very similar manner, only that - contrary to the models of the DSGE class - they allow for a true evaluation of their micro and meso foundations, and the concrete mechanisms implemented in the model.<sup>51</sup> ACE models can thus be thought of as a set of various hypothesis about the system under investigation, i.e. its properties, mechanisms, and future dynamics, which are tested at once.

Also, ACE models allow integrating information from qualitative research in a much more direct way than the majority of formal models currently available in economics: due to their algorithmic design, qualitative answers of questionnaires can be mapped to mechanisms in the model much more easily than if everything in the model was written in equation form.<sup>52</sup>

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<sup>50</sup>Some argue that this move was counter-productive and that macroeconomics should be more focused on the statistical analysis rather than imposing the questionable assumptions necessary to derive a workable DSGE model (e.g. P. Chen (2010)). I argue that ACE models are the preferable option to proceed with because they are more theory-driven than pure econometrics and machine learning, *and* provide the freedom to use theory beyond the conventional general equilibrium framework.

<sup>51</sup>One example of where the empirical assessment of DSGE models regularly fails is the test of how well the Euler equation matches the data: they usually simply do not fit the data (Canzoneri, Cumby, & Diba, 2007). The fact that both the micro assumptions and the meso consequences are severely at odds with reality should cast doubt on the statement that DSGE models are 'microfounded' macro models.

<sup>52</sup>This fact is a direct consequence of Newell and Simon (1972) who claim that human decision making is algorithmic: human decisions are usually easily expressed via algorithms, but to translate them into equations or even maximization problems is by far more difficult and error-prone.

### 1.4.6 Summary: Agent-based computational models and a generative social science of complex systems

This section addresses one of the key questions that emerges from the ontological and epistemological frameworks developed before: how can one study complex economic systems and learn about how they work?

Two important conclusions emerge from this section: firstly, there is no single method that is adequate for all situations in which knowledge about complex economic systems is sought. Secondly, the method of ACE modeling takes a special place in the set of adequate tools, because it is the only formal method that meets all ultimate criteria of the epistemology derived from the ontology of complex systems. It is therefore of central importance for the study of complex economic systems. The reason why nevertheless other modeling approaches are required is that ACE modeling is not without problems and important intermediate results can be gained rigorously with other modeling approaches, such as recursions, replicator dynamics, or evolutionary game theory.

In the end, ACE models are an indispensable tool for the systemist analysis of complex economic systems: The explanations offered by them are *generative* and it is straightforward to build *mechanismic* explanations in the ACE framework. Furthermore, they are well suited to investigate the interaction effects of different mechanisms, e.g. whether a certain bargaining mechanism yields different results if the population is characterized by a scale-free interaction structure or a complete interaction structure (S. Page, 2012). This means that the results obtained by simpler, analytical models can and should be used as a starting point for more complex ACE models that can be used to explore the consistency of results obtained by different analytical models and merge them into more complex and general theories.

Another important aspect of ACE models is that they stimulate researchers to think in terms of *computations*, i.e. in algorithms. This is important for social scientists because humans usually think algorithmically (Newell & Simon, 1972; Gigerenzer & Selten, 2001; Berg & Gigerenzer, 2010) and consequently all social structures involving human reasoning must somehow refer to computational terms. The language suggested by object-oriented programming provides an intuitive and rigorous way to express these computational terms in a formal way. But this also means that formalizing a theory in computational terms can itself advance this theory - beyond the usual advantages of formalization. In the next section, for example, I will argue how the computational terms provided by the method of ACE modeling can help to refine the theoretical concept of an institution and thus advance institutional theory as such - beyond being useful as a formalization device.



## 1.5 How institutionalism benefits from the theory of economic complexity

The preceding part of this introduction was mainly concerned with the provision of a solid foundation for the study of complex economic systems, enriched with theoretical content from other social sciences and economics.

In this section and the upcoming chapters I now turn to the question of how evolutionary-institutional economics can benefit from a theoretical and, in particular, methodological transfer *from* the field of complexity science. To illustrate this, consider again figure 1.1: while the first sections were about the upper left part, we now consider the lower left part of the figure.<sup>53</sup>

To this end, I firstly claim that institutionalist economists implicitly concern themselves with complex economic systems (section 1.5.1). This means that from an ontological viewpoint, a knowledge transfer from complexity to institutionalist theory is conceivable. While having produced a very rich body of theory, institutionalism lacks adequate formal modeling tools to study economic systems more deeply (section 1.5.2). Using methods from complexity science in institutionalist research therefore bears the potential to eliminate this weakness and seems to be a promising area of further research. Finally, as I argue in section 1.5.3, this is particularly true because beyond the methodological contribution, ACE models can contribute to institutionalist theory directly.

### 1.5.1 Institutionalism is about complex economic systems

Based on the ontological definition of complex systems elaborated in section 1.2.3, I claim that the research object of evolutionary-institutional economics is the economy as a complex system:

An economic system is complex if it consists of potentially heterogeneous and potentially adaptive parts, among which their relations are (at least partly) self-organized so that they make up an *systemic whole* in the sense that the interactions among the parts are nonlinear and that this whole possesses some features that its components lack.

Institutionalists reject the idea of a *representative* individual because they claim that heterogeneity is a key aspect to be considered (Veblen, 1897; Hodgson, 2004; Hildenbrand, 2014). One important reason for this is the tension between inherited instincts, different motivations and the resulting moldability of humans and their behavior. The corresponding debate dates back to Smith (in particular Smith (2011 [1759])) and Veblen (in particular his criticism of Marxist materialism in Veblen (1897)) and has been continuing to be an important debate in evolutionary-institutionalist economics with important new insights from the cognitive sciences entering the debate (e.g. Vromen (2003)).

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<sup>53</sup>Because the main arguments are central aspects of the upcoming chapters, this section merely sketches the argument. The detailed elaboration of the arguments comes in the chapters that follow.

Furthermore, individuals are generally considered to be *directly interdependent* and *socially embedded* (Elsner et al., 2014). They also emphasize the role of institutions and other social structures that exist on a different ontological level than that of the individual parts. Institutions, for example, are now considered to depend on individuals, but also affect their behavior through a reciprocal relationship (Searle, 2005; Hodgson, 2006). This idea expresses itself in a layered ontology consistent with my conception of a complex economy (Hodgson, 2004). Furthermore, the concept of *self-organization* is also implicitly present in institutionalist reasoning: because although centralized actors such as the state or transnational companies receive particular attention, the focus on a rich conception of individual agency (Veblen, 1897; Hodgson, 2004; Cordes, 2009) and the consideration of social structures into which individuals are embedded implies the rejection of centralized control mechanisms that leaves no room for individual and dispersed decision making (see also section 3.3.2, and Hodgson (2007), Elsner (2012), Elsner et al. (2014)).

Thus all elements of the ontological definition of a complex systems are met by the research practice of institutionalism. This suggests the potential for a closer collaboration between institutionalists and complexity economists. One of the major motivations for such a collaboration from an institutionalist perspective is that complexity scholars can address one of the central weaknesses of institutionalism in its current form: a lack of adequate formal modeling tools that allow to unravel the mechanisms of the complex economic systems institutionalists are interested in.

### **1.5.2 Institutionalism lacks adequate methods**

Some argue that institutionalist economics is opposed to formal modeling *per se*. Wilber and Harrison (1978), for example, claim that *the* method of institutionalism is the *participant-observer approach*, a method originating from anthropology and of purely verbal character. I argue, however, in chapter 5 that institutionalism is not completely opposed to formal modeling, but just formulates very high demands for formal methods. There are indeed a few formal methods used in institutionalism that I review and discuss in this chapter. During the methodological debate about these methods, several arguments were made repetitively: For example, both Radzicki (1988) and Elsner (2012) criticized an alleged lack of logical depth of verbal institutionalist pattern modeling (a fact that also is acknowledged by Wilber and Harrison (1978, p. 87)). Another drawback of the reluctance to use formal methods is a focus on very detailed case studies, rather than the identification of more general insights (such as mechanism-based explanations), an argument already made by one of the founding fathers of institutionalism, Wesley Mitchell (Hirsch, 1994).

Also, if institutionalists are really aspiring to study the economy as a complex system, then issues such as the particular compositional structure of the systems, the relations among the actors, the mechanisms underlying the aggregation of individual behavior, and the interactions

among different mechanisms *must* be studied explicitly. To fulfill this task without a recourse to formal methods does not seem to be conceivable. For example, even to *express* the particular compositional structure of an economic system with even moderate precision *requires* concepts of network theory. And to use existing data about these structures, and to elaborate on the consequences of this structure without using the precise language of graph theory is simply impossible.<sup>54</sup>

The potential that lies in the application of formal modeling is also illustrated by the recent progress of modern evolutionary economics (the other current branch of evolutionary-institutional economics today): in their studies of innovation, industrial dynamics, and technological change, neo-Schumpeterian economists frequently used dynamic tools from mathematics to substantiate their arguments, to generalize their results, and to test the empirical adequacy of their theories. Contributions of evolutionary economists to topics more closely associated with the institutionalist branch of evolutionary-institutional economics also illustrated the usefulness of mathematical modeling, if applied adequately (see e.g. Cordes (2006)). In chapter 4 I argue that particularly the method of ACE modeling is consistent with the theoretical demands of institutionalism, but also make the claim that the methodological umbrella of ACE bears the potential to bring the institutionalist and the modern evolutionary branch of evolutionary-institutional economics closer together again.

To summarize, there is an effective deficit of formal modeling tools in current institutionalism and the provision of adequate modeling techniques could significantly advance institutionalist economics. As it will be shown in the chapters that follow, ACE modeling can be used to exploit this potential.

### 1.5.3 ACE modeling can advance institutionalist theory

ACE modeling does not only serve as a viable research tool. By introducing the adequate language to formalize computational reasoning, it can also directly enable superior *theorizing*:

One example for this is provided by the fact that ACE models do explicitly and intuitively refer to the theoretical concept of *computation*. This is usually not possible in analytical models: they are either concerned with the *consequences* of individual behavior (as in the case of evolutionary game theory, replicator dynamics or system dynamics), or confined to *as if* arguments in the spirit of Friedman (1953) - an unattractive alternative for institutionalists who are (critical) realists rather than instrumentalists. For them, it is important to note that in the end every person *does make* computations when making decisions.<sup>55</sup> And the human brain performs these computations in an algorithmic manner: there is now plenty of evidence that the human

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<sup>54</sup>I provide more examples of issues where a formalization would be very beneficial to institutionalist research in chapters 4 and 5.

<sup>55</sup>The term *computation* is used in its original meaning, i.e. executing an algorithm. Or, more formally, the actions undertaken by a Turing machine or any comparable theoretical computer model.

brain does not maximize anything like a utility function, but uses heuristics to carry out the computations necessary to reach a decision (Newell & Simon, 1972; Simon, 1981; Gigerenzer & Selten, 2001; Gigerenzer & Gaissmaier, 2011).

This fact is not only the result of the superior accuracy-effort ratio of heuristics: whenever agents face a situation of true uncertainty rational expectations are not defined any more. In this case heuristics also are the best option available to the decision maker and produce better results than rational choice models relying on estimating the uncertain parameters of the decision framework (Berg & Gigerenzer, 2010).

The modeling techniques that institutionalists use to study human decision making should therefore be able to (i) explicitly represent heuristics, (ii) allow for decision making under true uncertainty, and (iii) provide measures for the particular cognitive capacities of the economic agent (Miller & Page, 2007; Bednar & Page, 2007). ACE modeling meets these criteria.

Now having such a modeling device at one's disposal is not only important for building descriptively accurate models: it also makes one think about particular questions that are usually overlooked in purely analytical models.

Consider the example of bounded rationality: in contrast to computational models bounded rationality is something that is not naturally part of an analytical model, but has to be included explicitly - a task that is far from trivial. In a computational, and particularly ACE modeling context, on the other hand, it is not only easy to account for particular heuristics explicitly, there are also a number of formal methods that allows the modeler to alter the degree of computational capacity of economic agents, e.g. by using genetic algorithms (Holland, 1975; Mitchell, 1999; Geisendorf, 2011, 5), or finite state machines (Rubinstein, 1998; Bednar & Page, 2007).<sup>56</sup> All these methods not only enable the researcher to model situations that could not be modeled with conventional modeling techniques - it bears the potential to make her also think about certain aspects of human decision making and its consequences in a much more advanced way.

Another example where such theoretical reasoning in agent-based computational terms has the potential to advance theory on its own is the definition of an institution: existing conceptions of institutions are either completely verbal (e.g. Searle (2005) or Hodgson (2006)) or rely mainly on game theory (e.g. Greif and Kingston (2011) or Elsner (2012)). Both approaches have their problems: the verbal definition remains necessarily imprecise and does not allow for a serious consistency check or the integration to more complicated and realistic formal models. The game theoretic conception, on the other hand, relies on the demanding assumptions on individual preference structures and makes it difficult to account for central pillars of institutionalist theory such as bounded rationality, path dependence, or the social embeddedness of the actors, and the way these concepts relate to each other. A computational definition of institutions (e.g. to consider institutions as networks of certain decision making algorithms) may capture all the essential aspects of institutions (i.e. their reliance on shared belief systems, their dependence on

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<sup>56</sup>Note that simple models in this context may still be solved without simulation (Lipman, 1995; Rubinstein, 1998). Nevertheless, the logic of such models is *computational*.

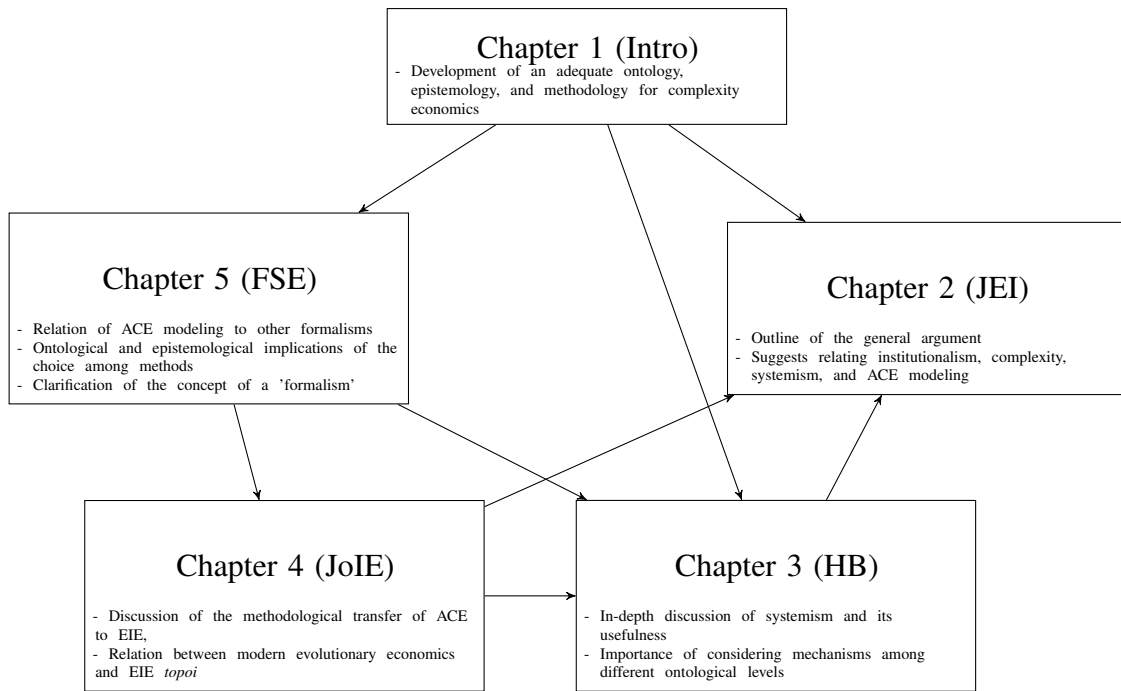


Figure 1.4: An overview of the different chapters of the dissertation. An arrow from one chapter to another means that the first refers to arguments more explicitly elaborated by the second.

some critical mass of followers, their ability to reduce the complexity of the decision making problems for individual agents, and their dynamic nature), but also allows putting them in a formal, yet algorithmic language and consider the role of institutions in more general models.<sup>57</sup>

These example show that the benefit of ACE modeling for institutionalism goes beyond the formalization of institutionalist theory, but also represents a direct theoretical value in itself.

## 1.6 An overview over the papers of this dissertation

In this section I give an outlook on the chapters that follow in this dissertation. For a graphical illustration of the relationship among the different chapters see figure 1.4. The arrows in the figure indicate that the introduction used several arguments that are elaborated more explicitly in following papers. Furthermore, while this introduction mainly focused on how new foundations for a research program of complexity economics can benefit from the theoretical contributions of institutionalism, the following chapters focus on the opposite direction, i.e. on how institutionalism can benefit from theory and methods of complexity theory.

As illustrated in figure 1.1, the introduction and the papers therefore complement each other.

<sup>57</sup>For a similar approach when it comes to conceptualizing *culture*, see Bednar and Page (2007).

### 1.6.1 New perspectives on institutionalist pattern modeling: Systemism, complexity, and agent-based modeling

In this article<sup>58</sup> we identify the theoretical proximity and relatedness among (1) original institutionalist theory, (2) the philosophical concept of systemism, and (3) the theory and methods of complexity economics. As such, it paves the stage for the chapters that follow.

The first part of the paper focuses on the affinity between institutionalism and systemism. Building upon the seminal contributions of Wilber and Harrison (1978) and Myrdal (1978), and considering the research practice within institutionalism thereafter, we argue that “systemism is an implicit cornerstone of institutionalist theorizing and modeling” (p. 64).

We elaborate on several examples that substantiate this claim: for example, a layered ontology is central both to institutionalism with its consideration of individual agency *and* social structures (see e.g. Hodgson (2004)), and systemism with its idea of sub- and super-systems and their respective parts (see e.g. (Bunge, 1996)). Also, Bunge’s focus on emergent properties and the resulting potential for both upward and downward effects aligns well with the particular attention devoted to the study of social institutions and their consequences for individual decision making in institutionalism (Gruchy, 1947; Hodgson, 2006; Elsner & Schwardt, 2014).

The second part of the paper links this reasoning to the fundamental dictum of complexity science, namely that “more is different” (Anderson, 1972). We sketch the argument that the concept of *organized complexity* as introduced by Weaver (1948) is very much what institutionalists have (implicitly) in mind when they describe the nature of the economy. But we also point out that the epistemological and ontological basis of complexity economics is still weak and not comparable to the theoretical foundations of institutionalism. This observation has been taken up in the first sections of this introduction when I tried to close this gap with the transfer of ideas from institutionalism and its systemist foundation to complexity economics. But the argument in this chapter goes in the opposite direction: we argue that institutionalism lacks adequate formal methods to study the economic systems it considers in more depth. Then we propose to consider agent-based computational modeling as a new baseline formalism for institutionalism: as ACE modeling is widely used within complexity science to study non-trivial aggregation relationships, and institutionalism shares this interest on aggregation mechanisms with complexity scholars, a methodological transfer to institutionalism seems promising.

The final part of the article therefore anticipates the main claim of chapter 4, namely that institutionalism can benefit greatly by exploiting the advantages of ACE modeling. The main argument besides the focus on aggregation procedures is in this article that ACE modeling allows

<sup>58</sup>The article was co-authored by Jakob Kapeller from the Johannes Kepler University in Linz. It was published in the June issue of the *Journal of Economic Issues* in 2015. For my personal contribution to the article see the attachment to the present thesis.

the incorporation of more realistic representation of real world objects. With respect to the aim of the article, this is a viable approach because institutionalism has a (critical) *realist* conception of science (Bhaskar, 1975; Cherryholmes, 1992; Hodgson, 2004; Hall & Whybrow, 2009). We use the example of Hodgson and Knudsen (2004) to show what such a liaison could look like, but leave the exact methodological discussion as an area of further research, which is taken up in subsequent chapters, in particular chapter 4 and 5.

This article provides a first consistent outline of the central arguments of the research program developed in this thesis. The particular arguments are then elaborated in more detail in the subsequent chapters and in this introduction: the consistency between ACE modeling and institutionalism is the central topic of chapter 4, the particular usefulness of systemism for institutionalism (and heterodoxy in general) is illustrated in chapter 3, and the potential of institutionalist theory and systemism for giving a sound philosophical framework to complexity economics was discussed in the first sections of this introduction. This chapter should therefore be considered a vantage point for the remaining arguments of this thesis (see also figure 1.4).

### 1.6.2 The micro-macro link in heterodox economics

This paper<sup>59</sup> extends the argument of the previous paper by showing that systemism can serve as a general philosophical framework for the study of the micro-macro link from a heterodox viewpoint. Because it is not focused on socio-economics or institutionalism, it is the chapter with the broadest perspective in this thesis. It extends several of the key arguments made previously, in particular the justification of an overall philosophical framework for the study of economic systems, the necessity for mechanistic explanations, and the consideration of both bottom-up and top-down effects.

We first establish the general importance of considering the micro-macro link explicitly in economic modeling. We do this by pointing to four general fallacies that can occur if such an explicit treatment does not take place: the failure of ignoring relations among different parts on the micro level of the system under investigation (the *simplistic fallacy*), the misleading assertion that all aggregate properties can be epistemologically reduced to micro properties (the *static fallacy*), the fallacious refusal of studying higher-level mechanisms on their own (the *dogmatic fallacy*), and finally the epistemological fallacy of *a priori* ignoring the possibility of downward causation (the *hierarchical fallacy*).

At this point, the chapter substantiates the arguments from section 1.3 by providing more concrete examples of how a model can fail to become a good surrogate for reality, if the com-

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<sup>59</sup>The article was co-authored by Jakob Kapeller from the Johannes Kepler University in Linz. It is going to be published in the *Handbook of Heterodox Economics*, edited by Tae-Hee Jo, Lynne Chester, and D'Ippoliti, and to be published by Taylor & Francis in 2016. For my personal contribution to the article see the attachment to the present thesis.

plexity reduction function is specified poorly with respect to the micro-macro relationship. Note that it has been argued earlier that ACE models can be used to identify these fallacies.

After establishing the necessity of an explicit treatment of the micro-macro relationship, we elaborate on how this challenge has been taken up by current heterodox approaches. We identify four different heterodox perspectives the micro-macro link that allow to circumvent the fallacies outlined before and show that these are potentially integrated with a general systemist framework for heterodox theorizing. Here, the chapter again extends and substantiates the arguments outlined in the previous chapter by introducing the concept of systemism in more detail, and to provide an in-depth justification for its usefulness in economic theory including some illustrative examples of how existing theories can be aligned with the systemist meta-language.

The chapter closes with the claim that systemism can serve as a common denominator for the different heterodox approaches to the micro-macro link, enabling mutual communication and comparability among them. This argument is important in three ways: firstly, it supports Elsner's claim for a *heterodox convergence* among socio-economics and institutionalism (Elsner, 2014). Secondly, it further supports the role I ascribe systemism in my framework for complexity economics in sections 1.2 and 1.3 because it again clarifies the importance of a common meta-language for a consistent research framework. And finally it provides evidence for my specific hypothesis of a *theoretical convergence* between evolutionary-institutionalism and complexity economics, because both approaches do (or should) be based on a systemist foundation (see also section 1.7).

### **1.6.3 Agent-based computational models - A formal heuristic for institutionalist pattern modeling?**

In this article<sup>60</sup> I elaborate on the methodological foundations of original institutionalism by taking into account the classical contributions of Myrdal (1978), Wilber and Harrison (1978), and Hodgson (1988), the recent discussions about a stronger orientation towards Darwinism, and the relation between institutionalism and modern evolutionary economics.

The first contribution of the article is therefore to identify the actual methodological foundations of institutionalism, reconsidering the classic contributions, and interpreting them in the context of recent advances in economic methodology and philosophy of science. In particular, I show that two fundamental methodological pillars of institutionalism, holism and systemism, are to be revised and summarized by the modern conception of systemism as it was outlined above. In clarifying the methodological base of modern institutionalist theory, I also consider recent ontological debates, in particular the important debate about the role of Darwinian principles

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<sup>60</sup>This article was published in the *Journal of Institutional Economics* as an *online first* article in June 2015.



in institutionalist and evolutionary economic theory: I show, that while the debate is important on a meta-theoretical level, the positions of those advocating a generalized Darwinism (Hodgson, 2002; Hodgson & Knudsen, 2010) and those arguing in favor of the so called continuity hypothesis (Witt, 2004; Cordes, 2006; Witt & Schwesinger, 2013), yield similar *methodological* demands. These clarifications also take into account the arguments made in the discussions about evolutionary game theory (Elsner, 2012) and system dynamics (Radzicki, 1988) and close an important gap in the theoretical literature about the methodology of institutionalism.

These results represent the vantage point for the second major contribution of the article, namely the detailed investigation of the consistency of ACE modeling with the methodological demands of institutionalism. The related discussion clarifies in detail what the potential advantages and pitfalls of ACE modeling are, both in the context of institutionalist economics, and in general: thus, the potential pitfalls identified and discussed are also important in the context of complexity economics, which is why this part of the article plays an important role in the whole research program I outlined in this introduction.

A third important contribution of this article is then the clarification of the relationship between institutionalism and modern evolutionary economics during the last decades: while these two research programs have their theoretical roots in original evolutionary-institutional economics, they have been moving along separately the last years.<sup>61</sup> Nevertheless there is hope of bringing them closer together under the methodological umbrella of ACE modeling. The article argues that this is an attractive research strategy, given that the major topics considered by the two communities are different, but closely related to each other: much of evolutionary economics is concerned with technological change, innovation, and industrial dynamics. Institutionalists have focused on the roles of institutions for growth, distribution and for policy making.

However, much recent work in both areas acknowledged the importance of institutions in the context of innovation and technological change, the central role of technology, innovation, and market dynamics for societal development, and the distribution of power and wealth (Iacopetta, 2008; Greenwood & Holt, 2008; Oleinik, 2013; Russo, Riccetti, & Gallegati, 2015; Franzini & Pianta, 2016).

To bring the results of institutionalist and evolutionary economics together and re-integrate them again in a new evolutionary-institutionalist economics therefore seems to be an attractive research outline. Such a program could successfully be based on the method of ACE modeling and would necessarily have a strong affinity with the research program of complexity economics outlined in this introduction (see also section 1.7).

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<sup>61</sup>Nevertheless their underlying ontology is still very similar. See for example the proposed ontology of Dopfer and Potts (2004) which is complementary to the ontology outlined in this introduction. I elaborate on this in more detail in chapter 4.

### 1.6.4 Formal Approaches to Socio Economic Analysis - Past and Perspectives

This final chapter<sup>62</sup> takes a slightly different starting point than the preceding one by focusing on social rather than institutionalist economics. This serves two purposes: firstly, it helps to broaden the applicability of my approach and establishes theoretical links to areas of economics beyond original institutionalism. Secondly, and more importantly, Elsner (2014) recently argued for a *heterodox convergence* in that different heterodox schools of thought are now converging to certain shared principles (I took up this important argument already in the context of the micro-macro link in heterodox economics, see chapter 3). His major example was the convergence between institutionalist and social economics. This chapter therefore assesses this claim in the sense that it considers formal methods in the context of both social and institutionalist economics. If it found significant similarities among the modeling practices of institutionalism and social economics, then this would be a convincing argument in favor of Elsner's thesis of a *heterodox convergence*.

The first important contribution of the article is a rigorous assessment of the *status quo* of formal modeling within social (and institutional) economics: After introducing an adequate definition of a *formalism in the broader sense*, it concisely introduces the most common formal approaches satisfying this definition: the social fabric matrix (Hayden, 2006a), system dynamics (Radzicki, 1988), the institutional analysis and development framework (Ostrom, 2011), and (evolutionary) game theory (Elsner, 2012). It then proposes ACE modeling as a new socio economic method.

Considering the debates on the introduction of these methods is particularly illuminating because several arguments come up regularly and independently of each other: both Elsner (2012) and Radzicki (1988) criticized the lack of rigor in purely verbal institutionalist pattern modeling and therefore suggested enriching the institutionalist toolset with game theory and system dynamics respectively. My epistemological claim is similar. But later in the article I compare the different methods to each other and conclude - *inter alia* - that there is a potential complementarity between game theory and ACE modeling, but not with system dynamics. So while I share Radzicki's methodological critique of institutionalism, I agree only partly to his methodological conclusions.<sup>63</sup>

The second contribution of the article is then the substantiated claim that there are no *virgin methods*: the choice of a particular form of modeling always entails certain ontological and

<sup>62</sup>This article was published in the *Forum for Social Economics* as an *online first* article in June 2015.

<sup>63</sup>Note that the discussion is about combining the methods in one single model. I do not deny that it can be illuminating to consider a phenomenon both from an ACE and system dynamics perspective. As elaborated in section 1.4.4, ACE models can also be used to assess the adequacy of the aggregation and homogeneity assumptions implicit in any system dynamic model.

epistemological convictions that are often not well reflected. I therefore clarify the implicit epistemological and ontological tendencies of all these modeling frameworks and summarize them in table 5.1. Already at this point, I will have identified ACE modeling as inherently affine to a systemist conception of the economy. These clarifications also illustrate the importance of a well reflected epistemological and ontological base for any research framework. Otherwise, the resulting models could be inconsistent and difficult to compare.

The third important contribution is the clarification of how the different methods relate to each other: I classify the approaches according to the distinction of *frameworks*, *theories*, and *models* by Ostrom (2011) and elaborate on potential complementarities and antagonisms among them. Note that this kind of distinction does not apply to the philosophical framework for complexity economics developed in the first sections of this introduction: This ontological and epistemological framework represents a meta-theoretical foundation for future research on complex economies. While it narrows the set of potential methods, it is less applied than the frameworks of Ostrom's classification, and less concrete than the theories in the classification: it may be possible to build a model that is based on Ostrom's IAD framework, theoretically informed and made concrete by institutionalist theory, but also consistent with and informed by the epistemological and ontological framework developed above. There is, however, a certain similarity among the role played by institutionalism in my foundation for complexity economics and that of a *theory* in Ostrom's taxonomy: institutionalism indeed added economic substance and concreteness to my foundation, as does a theory in Ostrom's framework.

In the end, this article serves the important purpose of summarizing the *status quo* of formal modeling in social and institutionalist economics, and in illustrating once again the attractiveness of a systemist perspective on the economy, in particular through the application of ACE modeling. It also provides further evidence to Elsner's thesis of a heterodox convergence, at least among institutionalist and social economics, by illustrating the *methodological* convergence of the two approaches. Finally, the paper clarifies the relationship among different formalisms currently employed by institutionalists and socio economists and thus provides a useful guidance for future research projects.

## **1.7 Conclusion and outlook: This dissertation as a starting point**

### **1.7.1 A convergence of heterodoxies?**

Elsner (2014) recently argued that there is a *theoretical* and *methodological convergence* between social and (Veblenian) institutional economics. He terms the resulting common research program "socio-economics" (Elsner, 2014, p. 2). Given the preceding elaborations, we may ask how the

research program of *complexity economics* as outlined above relates to socio-economics, and to what extent institutionalism is itself transforming into some sort of complexity economics.

Currently, institutionalism and complexity economics are still largely separated: there is only a small number of researchers that consider themselves part of both research communities and who foster an effective knowledge transfer between them. The present work aims at effecting such a mutual transfer of knowledge by referring to institutionalist concepts when building a philosophical framework for complexity economics, and by effecting a methodological transfer from complexity to institutionalist economics. This hopefully brings about a closer collaboration among the two communities as the preceding elaborations revealed a considerable number of complementarities and similarities between these approaches. But it will take a long time until an effective convergence will take place. The reason for this is pragmatic rather than theoretical: currently, the background of scientists working explicitly on economic complexity is very different to classical institutionalist economists: while the former often come from fields such as mathematics, computer science, physics, or biology, the latter mainly come from the fields of political economy, sociology, political science, and history. This entails a different language, different research institutions (including different associations and journals), and a different research culture with institutionalists focusing much more on issues such as ethics, normativity, justice, and fairness than most complexity economists (compare, for example, the methodological contributions of Farmer (2013) with that of Hayden (2006b)). And as until now complexity economics (in contrast to institutionalism) has had no consistent philosophical foundation, it was particularly difficult to identify and exploit the complementarities and to resolve the differences between complexity and institutionalist economics. Nevertheless, thanks to the explicit ontology and epistemology provided earlier, theories and models of complexity and institutionalist economics can now be compared and aligned much more easily. Through this process we may then develop the 'shared meaning' (Hodgson, 2015) required for enhanced scientific cooperation.

### **1.7.2 The future of complexity economics**

Irrespective of whether there will actually be a full (or partial) convergence of complexity, social, and institutionalist economics, the emerging research program of complexity economics faces a promising future.

Departing from the solid ontological, epistemological, and methodological foundation provided above, there is a large set of urgent questions that call for being studied from such a complexity perspective. Examples range from very theoretical to very applied cases and include the following:

1. Social power is frequently considered to be of central importance for economics (e.g., Galbraith (1973), Kapp (1976), Rothschild (2002), or Wäckerle (2014)), but remains a

completely unformalized and vague concept.<sup>64</sup> As power is concerned with individuals, their relations, and social positions and institutions, it is predestined to be studied through theory and methods of complexity economics. Considering recent advances in conceptualizing culture (Bednar & Page, 2007), and, hopefully, institutions (see above), this seems to be a promising way for further research.

2. The strong relation between institutions, innovation, and technological change has been emphasized by many economists from very different orientations ever since, e.g. Schumpeter (1942), Ayres (1996), Acemoglu and Robinson (2000). Up to now, these topics were the subject of quite different research paradigms that have not yet brought together their theoretical and empirical results. Modern evolutionary economists have made considerable progress in understanding technological change and innovation by using tools from complexity economics, in particular ACE modeling and network analysis. As the potential for applying these tools and the corresponding theory of economic complexity to the study of institutions is one of the central messages of the chapters that follow, a joint consideration of the three topics under the umbrella of complexity economics would be a logical next step. This would come close to the vision of economists such as Schumpeter and Ayres who anticipated such a unified treatment a long time ago.
3. Economic and social development has been one of the key topics for economists ever since. Most of the existing theories are unfortunately not satisfactory at all, since “despite the considerable amount of research devoted to economic growth and development, economists have not yet discovered how to make poor countries rich.” (Azariadis & Stachurski, 2005). One reason for this might be that there is tons of fragmented evidence for particular mechanisms or institutions that could be the cause for underdevelopment, but there has never been the attempt of an integrative approach to study e.g. the mechanisms underlying the distribution of wealth and the role played by technological change and the institutions into which these processes are embedded in one coherent model. Complex simulation models could fill this gap, in particular because a significant body of theoretical and empirical literature already exists: the simulation models could be built from sound theoretical basis so that overparametrization could be avoided (see above section 1.4.3). Further these topics are predestined to be studied from a complexity perspective because of ontological reasons: the heterogeneity and the particular dependence structure of the actors involved is important, the relevant mechanisms operate on different ontological level and interact with each other, and the ongoing dynamics of the processes including positive feedback loops make the application of equilibrium models particularly doubtful.
4. The theory of economic complexity not only entails important policy implication in general (Elsner, 2015). As it became clear from the epistemology of complexity eco-

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<sup>64</sup>Or it is defined purely in competition-based terms such as pricing power in monopolistic markets or bargaining power in certain classes of games. See Rothschild (2002) for a critique.

nomics elaborated above, the kind of explanations provided by complexity economics are *mechanism-based* and *generative*. This also means that they can more easily be transformed into policy advice than the outcomes of general equilibrium models. Moreover, ACE modeling as a method is predestined to conduct policy experiments and related forms of counterfactual analysis (Moss, 2002; Dosi, Fagiolo, & Roventini, 2010; Borrill & Tesfatsion, 2011). The main reasons besides their generative nature is their ability to consider feedback mechanisms, adaption processes, and higher order effects of policy interventions directly. There is simply no alternative modeling device that meets the demands of developing particular policy measures as perfectly as ACE.

These areas of study all embrace aspects that were studied quite extensively in isolation by either classical institutionalists, modern evolutionary economists, complexity economists, social economists, or others. To bring them together under the framework of complexity economics as outlined in this thesis will help to finally unify the dispersed theoretical fragments. This will result in a full-fledged interdisciplinary, real-world oriented, and policy relevant research program that will prove useful in tackling today's urgent questions of economics and society.

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## **Chapter 2**

# **New Perspectives on Institutional Pattern Modeling: Systemism, Complexity, and Agent-Based Modeling**

### **Chapter Abstract**

This paper focuses on the complementarity between original institutional economics, Mario Bunge's framework of systemism, and the formal tools developed by complexity economists, especially in the context of agent-based modeling. Thereby, we assert that original institutional economics might profit from exploiting this complementarity.

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## 2.1 Introduction

Since their emergence, institutional economists have discussed potential philosophical underpinnings of institutionalist theory, as well as the appropriate role for formal modeling tools in economic thinking. In this paper, we use the classic methodological contributions of Myrdal (1978) and Wilber and Harrison (1978) as a starting point to illustrate the affinity between original institutionalism and the concept of systemism as summarized and refined in the writings of the eminent philosopher Mario Bunge. Systemism thereby puts an emphasis on the relations between individual agents or entities, which constitute an aggregate system. Such a relational perspective implies that different ontological levels are mutually interdependent, since individuals are always relationally embedded, allowing for the whole to influence its parts and for the parts to influence the whole. As a consequence, the question of aggregation of individual behavior is seen as an interesting and potentially complicated theoretical problem instead of being understood as merely an arithmetic procedure of “summing up”. This perspective aligns well with the growing research on economic complexity, which provides a similar account on aggregation within social systems. While complexity economics is often vague on its epistemological and ontological fundamentals, it has developed a rich toolset of formal models tailored to the analysis of complex social systems. We take the writings of Weaver (1948) on complexity as a vantage point of showing how complexity aligns with systemism and institutional economics. In doing so, we search for potential complementarities between these concepts, and how these complementarities might be exploited. In particular, we discuss the potential of using agent-based models within institutionalist research.

This paper is structured as follows: Section two introduces the philosophical concept of systemism, and illustrates how it aligns to institutional thought and complexity economics as well as possibly provides a unifying framework for these two approaches. Section three tries to develop a specific example of the general argument sketched in section two by referring to the use of agent-based models in institutionalist analysis. Section four contains our conclusions.

## 2.2 Systemism, Complexity, and Institutional Pattern Modeling

Although the label of systemism might seem novel, the corresponding ideas regarding research practice are far from being entirely new. In his various writings on systemism, Mario Bunge provides a series of illustrative examples for “systemist” social research. In this context, Bunge gives due credit to a series of well-known institutional economists, whom he conceives as systemist researchers — in particular, he mentions Gunnar Myrdal (Bunge, 2012, p. 30), Max Weber, Joseph A. Schumpeter, Thorstein Veblen, and K. William Kapp (Bunge, 1979, p. 92-93), as well as John Maynard Keynes and Wassily Leontief (Bunge, 2004, p. 187). Bunge’s

observation suggests a clear affinity between the concept of systemism and institutionalist economics.

In his account on systemism, Bunge asserts that any object or entity is either “a system or a part of one . . . [whereby] a system is a complex object, every part or component of which is connected with other parts of the same object in such a manner that the whole possesses some features that its components lack — that is, emergent properties” (Bunge, 1996, p. 20). Hence, he ties the concept of a system to the idea of related nodes forming an aggregate with some emergent properties. These emergent properties carry mechanisms, whose effects lead to continuous effects of change and stabilization, because of which we conceive of them “as a process (or sequence of states, or pathway) in a concrete system, natural or social” (Bunge, 2004, p. 186). These mechanisms are mostly “concealed,” and thus “have to be conjectured” (Bunge, 2004, p. 186, which constitutes an important parallel to the natural sciences. Some mechanisms are “essential” in that they are unique to a given system (Bunge, 2004, p. 193), and that they potentially carry “specific” functions that may be used to achieve specific goals. While mechanisms can be distinguished from functions (the former answer how things work, while the latter show how to achieve a given aim), they can still be mapped onto each other. In this context, the function-mechanism relation is principally one-to-many, since different mechanisms can be used to achieve a specific aim. Success on markets, for instance, can be achieved through a variety of mechanisms, hence “markets can be conquered” on different ways, for example, “by force, dumping, free-trade agreements or even honest competition” (Bunge, 2004, p. 194).

Any system can be characterized by a specific composition (the set of nodes), an environment and a certain structure or organization (the collection of relations between the nodes as well as between the nodes and the environment). The latter is a novel and necessary element of any system as well as the source of emergent properties, hence mechanisms. For instance, the degree distribution of the network structure representing scientific communication, which often follows a power-law, is intrinsically related to what Robert K. Merton famously termed the “Matthew Effect”, i.e., the mechanism allocating prestige to different scientists, which is determined by the relative prestige these scientists have accrued in the past (Merton, 2011; de Solla Price, 1965). Thus, one main contribution of systemism from a practical perspective is its capacity of putting the most interesting aspect of any system and structures therein — e.g., the organization of relations — at the center stage. While this basic concept of a system can be applied to a variety of concrete or even conceptual items, for the matter at hand, we can explicitly apply it to social systems like a family, a firm, or a nation. Therefore, novel properties emerge at the level of the whole system (global properties, such as a firm’s success or failure), or at the level of its individual components (relational properties, such as the role assigned to a given employee). By focusing on the relations between individuals, systemism aims to transgress the traditional dichotomy of individualist and holist approaches, and thereby to preserve “the grains of truth” involved in these approaches. Following this argument, Bunge juxtaposes systemism

	Individualism	Holism	Systemism
Ontology	A society is an aggregate of persons - any super-individual totalities are fictitious.	A society is a whole, transcending its members due to emergent and non-reducible collective properties.	A society is a system composed of changing subsystems and has global properties, both reducible and non-reducible.
Methodology	Social science is the study of the individual, and to explain a social fact amounts to explaining individual action.	Social science is the study of social wholes since only they may constitute social facts, which, in turn, determine individual behavior.	Social science is the study of social systems; their changing composition, environment and structure, as well as the mechanisms they bring forth.

Table 2.1: Individualism, Holism, and Systemism in Comparison

to individualism and holism by referring to three different layers: ontology, methodology, and morals (Bunge, 1996, 2000). Table 2.1 gives a stylized representation of the differences between three distinctive approaches with respect to ontology and methodology, which are in the focus of this paper.

The idea of systemism is not entirely new to institutionalist economics. In their classical methodological papers, Myrdal (1978) and Wilber and Harrison (1978) already emphasize both, systemism and holism. According to their definitions, the former means that the patterns emerging from the joint behavior cannot be derived from analyzing a single agent in isolation, while the latter was meant to accentuate the importance of potential downward effects in social systems. In this context Bunge’s main contribution to institutional economics is in explicitly clarifying the double role of emergent properties in this specific context, which are constituted by joint interaction, and thus may carry mechanisms of downward causation. Hence, in Bunge’s account of systemism, the complexity introduced by relations may give rise to mechanisms of downward causation, thereby rendering the reference to holism superfluous by deriving the possibility of downward causation from the original proposition that “parts are so related that their functioning is conditioned by their interrelations” (Gruchy, 1947, p. 4) . The fact that, for Bunge, social systems and their constituents are inherently dynamic provides another parallel to the classic account of Wilber and Harrison, 1978, who assign an important role to evolutionary thinking. Given this background, it seems fair to say that systemism is an implicit cornerstone of institutionalist theorizing and modeling.

Moreover, a close reading of Wilber and Harrison (1978) also suggests that a high priority was given to understanding the relation between different ontological levels of the economy. A similar emphasis can also be found in Bunge (1996), who argues that “social sciences study

social systems and their subsystems and supersystems” (p. 273). He recognizes that any system carries emergent properties as ontological novelties, which may come in two forms: either the system possesses some properties that its parts do not possess (global properties), or the parts possess some properties exactly because they are part of a given system (relational properties). Therefore, the approach to understand emergent properties as ontological novelties is rather a universal take on the question of whether “more is different” (Anderson, 1972).

Systemism further posits that different ontological levels in social research — no matter where these levels are exactly located in a given application — are bridged by mechanisms (additionally to within-level mechanisms), which replace those simple aggregation rules that are exemplified by typical formal procedures (e.g., summing up, calculating a mean, classifying, etc.). The question of “aggregation” is explicitly tackled as a potentially interesting theoretical problem and not primarily as a technical difficulty. Thereby, these “bridging” mechanisms can take the form of agency-structure relations (i.e., a bottom-up mechanism or upward causation), or structure-agency relations (i.e., top-down mechanisms or downward causation).

Institutionalists have already developed numerous candidates for such bridging mechanisms in their (mainly verbal) models, such as, for example, the concept of reconstitutive downward effects (Hodgson, 2002, 2006, 2011), or social emulation (Veblen, 1898). The question of whether there are more formal tools that can help institutionalists understand aggregation via mechanisms, as suggested by systemism, has led to another stream of literature, known as complexity economics. This line of research has developed numerous, mainly formal tools that allow for studying the economy as a complex system. Although the idea of complexity developed independently from systemism and institutionalism, the similarities of the theoretical frameworks are striking. The concept of complexity dates back to, at least, 1948, when Weaver made the important distinction between simple and complex scientific problems. Simple problems include only very few variables and were studied by pre-1900 physics and engineering. All problems, involving living organisms, can never fall into this category as they involve many different aspects and interrelated factors that can hardly be separated (Weaver, 1948, p. 537-538). Weaver distinguished between organized and disorganized complexity. A system consisting of many components shows disorganized complexity if some emergent pattern exists because the linear interactions between the different elements smooth each other out. The Law of Large Numbers can be interpreted as such an emergent pattern. Econometric work generally assumes this kind of complexity when it takes error terms to be identically and independently distributed. By contrast, a system showing organized complexity exhibits patterns that emerge because the interactions of the different elements do not smooth each other out (i.e., are non-linear). In such a case, there is a kind of self-organization of the system, so that the factors are interrelated into an organic whole (Weaver, 1948, p. 539).

While the analytical models of neoclassical economics presume the economy to show disorganized complexity, the perspective of institutionalist modeling expects the economy to be

characterized by organized complexity. The strong theoretical affinity between the complexity approach to the economy and the perspective of institutionalism/systemism suggests numerous potential complementarities. In particular, institutionalists might find some of the formal tools of complexity economics adequate to enhance the generality and the rigor of their verbal pattern models. On the other hand, complexity economics is a very diverse field that lacks a general epistemological and methodological foundation. In this context, systemism might provide both accounts with a common philosophical framework and a general platform for the discussion and development of theoretical arguments.

In the next section, we assess the potential of one particular tool, often related to complexity economics — agent based modeling. We do this in order to enhance and complement institutional pattern modeling aiming to gain a deeper understanding of the systemic properties of complex economic and social systems.

### **2.3 Systemic Analysis: A Plea for Agent-Based Models in Economics**

Agent-Based Models (ABMs) are usually expressed via a programming language and aim to represent situations, where individual actions lead to patterns, which, in turn, reflect on individual behavior. One can conduct artificial experiments by changing an aspect of the model, and then study how this affects the dynamics of the system under observation. While ABMs are considered to be formal models, they differ from the strict analytical framework of conventional economics as the modeler is not forced to make assumptions in such a way that the system stays analytically tractable and exhibits a clear equilibrium. Because the models are solved computationally, assumptions can be made on entirely proper considerations. In particular, agents' behavior does not have to be represented via convenient equations, but agents are more intuitively specified by attributes and rules implemented in a certain programming language. Such a specification of the agents allows the natural implementation of heuristics, learning behavior, and habits into the methods of the agent objects. The social embeddedness of agents is considered through an underlying — possibly changing — graph that specifies the neighborhood of an agent, i.e., the set of agents it can interact with. Depending on the degree of realism implemented in crafting the model, such a graph could represent a simple grid or an actual interaction structure among the agents. The advantages, in contrast to conventional economics, are twofold: First, there is a greater degree of freedom regarding the specification of individual behavior. Second, the interdependence of the economic agents is taken into account, so that group formation and dynamic power relations among agents can be explicitly modeled. Both aspects, in turn, allow for introducing more realism in economic modeling.

Because agents' rules may not only consider the current state of an agent, but also that of other single agents, a group of agents, or the state of the system as a whole, the interdependence

of different ontological levels can be directly implemented in an ABM. Another particular feature of ABMs, in comparison with analytical models, is that they refrain from assumptions about fictitious central planning mechanisms, such as the Walrasian auctioneer. Consequently, they allow the study of the economy as a self-organizing system without central control. The overall dynamics is then truly the result of the interactions of its constituent parts and the interplay of different ontological levels.

The resulting models are very diverse. There are ABMs that aim to be as realistic as possible and are extremely complex, while others try to illustrate a certain mechanism or a combination of mechanisms and remain rather abstract. Not all potential ABMs are compatible with institutionalist methodology and theory and, in most cases, the ABMs are only one piece of a broader institutionalist analysis of the problem at hand. Nonetheless, the following example illustrates what institutionalist ABMs could look like, and what role they can play in a broader analysis.

Hodgson and Knudsen (2004) use an ABM to illustrate the importance of habit formation for the emergence of social conventions in a setting, where reconstitutive downward effect plays an important role and the different ontological levels of the system under investigation are strongly interrelated. The authors study the emergence and evolution of a simple traffic convention, where agents drive cars on a ring structure — half of them clockwise, the other half anti-clockwise. At every round, each driver has to decide whether he/she wants to drive on the right or on the left. The authors clarify that the experimentation with different decision rules in their ABM helped them identify a surprisingly easy, but very effective decision procedure (Hodgson & Knudsen, 2004, p. 23). That is, drivers develop a habit of driving either on the left or right side and the model shows how the presence of habit fosters a convergence to a drive-left or drive-right convention. The model also shows that habit formation alone is not sufficient for the emergence of the convention, but has to be supplemented by a selection mechanism to lead to a stable traffic rule. Due to the modular structure of their ABM, Hodgson and Knudsen (2004) were also able to study what happens if habit is substituted by inertia, which resulted in less convergence in terms of traffic rules. Based on these findings, they conclude that the functioning of institutions is best interpreted as influencing habits rather than behavior or preferences. This application illustrates how ABM can be used to study different mechanism and their mutual influences on each other in one coherent model. Other recent examples of papers that successfully make use of ABM to implement an institutional pattern model include the following: Elsner and Heinrich (2009), who focus on the meso-level of the economy, use an ABM to study the group sizes and agency mechanisms that foster cooperative behavior among agents and use their findings to provide a model-based rationale for the existence of a “variety of capitalism” (Hall & Soskice, 2011). Rengs and Wäckerle (2014) build an extensive ABM of the European Monetary Union. They include fundamental institutionalist concepts such as conspicuous consumption in a model that represents both the real and the financial sector of several countries, including their political

institutions, and allows for a dynamic analysis of different institutional settings. Wäckerle, Rengs, and Radax (2014) illustrate the impact of trust and leadership on the life cycles of social institutions. Compared to classical game theoretic contributions, their agent-based framework allows them to study the interplay of agency and social structure more explicitly.

## 2.4 Conclusion

We argued that institutionalists can benefit greatly both from the philosophical framework of systemism and the application of ABMs as one possible operationalization of this general framework. In some classic methodological research, institutionalist authors identified holism, systemism, and evolution as the cornerstones of institutionalist analysis. Bunge's concept of systemism ties together all these ideas in one coherent framework, labeled systemism. We tried to show that this systemist perspective on the economy aligns well with a conception of the economy as a complex system. Building upon the definition of organized complexity due to Weaver (1948), we argued that there are considerable complementarities between complexity economics and original institutionalism, which are easily accessed from a systemist viewpoint. Finally, we illustrated our claims by referring to a simple ABM (Hodgson & Knudsen, 2004), which incorporates some of these complementary aspects. The above said, of course, does not mean that ABMs substitute a broader analysis, but have to be embedded into an adequate institutionalist process story in order to get epistemic meaningfulness.



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# Chapter 3

## The micro-macro link in heterodox economics

### Chapter Abstract

This paper provides an introduction to a unifying heterodox approach to the micro-macro link in economics. It emphasizes the analytical problems that may arise from popular misunderstandings about the relationship of individual and aggregate level and thereby illustrates why a thorough understanding of aggregation and aggregates in science is necessary.

In particular, we show that existing heterodox approaches to the micro-macro link in economics are not only consistent, but complementary to each other. We then propose a ‘systemist’ framework and show that heterodox economic theory and research practice can be substantiated and summarized by a more general, philosophical framework on aggregates and aggregation in science.

We argue that such a general philosophical framework will be helpful in advancing heterodox theory because it allows scholars from different heterodox starting points to relate their theories to each other via a consistent meta language and to explore the commonalities and differences in various heterodox approaches to the micro-macro link in economics.

Such a practice will facilitate a ‘heterodox convergence’, as in the case of evolutionary-institutional and social economics (Elsner, 2014), or help to ensure a transparent relationship in the form of productive disagreement, rather than a unreflected co-existence of the different approaches.

A productive scientific endeavor requires a common denominator for the different approaches enabling mutual communication and comparability. We argue this missing component is exactly what systemism can supply.

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This chapter is going to be published in the *Handbook for Heterodox Economics*, edited by Lynne Chester, Carlo D’Ippoliti, and Tae-Hee Jo. The handbook will be published by Routledge and will appear in late 2016.

### 3.1 Introduction

Any discussion of the micro-macro link in heterodox economics entails two main questions. The first question is relevant for social sciences in general and asks for the correct or adequate treatment of aggregates and aggregation in social theory. Any answer to this general question incorporates a series of diverse philosophical viewpoints, including ontological claims (e.g. do social and economic aggregates exist?), epistemological questions (e.g. which role is played by aggregates in aggregation in the context of economic theory?) and methodological aspects (e.g. how to adequately model processes of aggregation?). Given that economics abounds in problems of aggregation – as in the case of market interaction, macroeconomic aggregates or interpersonal coordination and contracting - the aim to provide suitable theoretical tools to adequately address aggregates and aggregation is of special interest to economists of different persuasions.

The second major question is more specific and asks for similarities and differences in the treatment of aggregates and aggregation among heterodox economists. From a traditional viewpoint one might question the idea that there is something like a consistent vision of the micro-macro link in heterodoxy, since different interpretations of the micro-macro link have been attributed to various heterodox strands of research. While some heterodox economists may prioritize either micro- or macro-level analysis, others emphasize the necessity to concentrate on the meso-level as a decisive intermediate layer between the more traditional approaches focusing on either microeconomic or macroeconomic aspects.

Against this backdrop this paper provides an introduction to a unifying heterodox approach to the micro-macro link in economics. In doing so, we first emphasize the analytical problems that may arise from popular misunderstandings about the relationship of individual and aggregate level and thereby illustrate why a thorough understanding of aggregation and aggregates in science is necessary (section 3.2). In a second step we show that the different heterodox approaches to the micro-macro link in economics are not only consistent, but complementary to each other and allow for a concise treatment of the micro-macro link in economics based on a set of shared fundamental principles (section 3.3). Eventually, we embed the heterodox economic view on aggregation in a ‘systemist’ framework and show that heterodox economic theory and research practice can be substantiated and summarized by a more general, philosophical perspective on aggregates and aggregation in science (section 3.4). We argue that such a general philosophical framework will be helpful in advancing heterodox theory because it allows scholars from different heterodox starting points to relate their theories to each other via a consistent meta language. The final section offers some concluding thoughts.

### **3.2 Aggregates and aggregation in science: an illustration of compositional fallacies**

Scientific endeavor often deals with the relation between aggregate entities, like a family, a nation or a firm, and their individual constituents – family members, citizens or employees. In disentangling this relationship between the ‘whole’ and its ‘parts’ errors may occur, which can be understood as compositional fallacies. Such compositional fallacies arise from either a wrong treatment of aggregation or a wrong treatment of aggregates and may lead to a deficient understanding of the whole as well as its parts. This section provides illustrations of four typical compositional fallacies and their conceptual sources with the aim to develop a basic understanding of the type of problems usually associated with the micro-macro link in the social sciences. For a more complete exposition of the particular fallacies, see Kapeller (2015).

One typical error related to aggregation is to underestimate the role of relations across individuals. Aggregates are not only composed out of individual entities, but also contain a set of relations which tie these individual nodes together and create a certain structure. Taking relations into account is often crucial for acquiring an adequate understanding of the constitution of aggregate entities. In fact, a central concern in feminist economists is to take individuals and their mutual relations instead of households as the starting point for economic analysis: otherwise, the important ‘aggregation procedure’ from individual to household preferences would eventually be neglected. However, it is the underlying relational structure among individuals that explains the often detrimental position of women as an aggregate result (Drèze & Sen, 1989). Taking the household as a fundamental economic actor therefore contributes to the exclusion of gender issues from economic analysis. This example illustrates that aggregation problems are central to economic analysis and appear in quite early stages of theorizing. As a general outlook on what follows, one might suppose that it is the rule rather than the exception that the behavior of some aggregate social system, like a family or a nation, strongly depends on its internal structure, that is, its relational setup.

Most standard economic models ignore relational setups entirely and simply posit that the aggregate behavior is obtained by some simple procedure of summing up across individual entities. The simplistic fallacy is thereby based on a deficient understanding of aggregation, which argues that the ‘whole’ is no different from the ‘sum of its parts’. Such a view is in conflict with two very basic observations: first, aggregates may develop properties no individual part possesses (e.g. a firm’s success). Second, individuals may acquire some properties exactly because they are part of some whole (e.g. a country’s citizen). In both cases we find that “more is different” (Anderson, 1972) as these newly acquired attributes can be conceived as emergent properties, i.e., some novel features arising exactly because an aggregate is constituted or sustained. For the case of families such novel properties include the possibilities of generating and raising offspring,

lending mutual support as well as creating collective identities and a collective organization of common rights and duties which may leave some family members in a dependent and potentially deprived situation compared with others. These aspects are often neglected, for instance, if households with multiple members are represented by a single utility function.

Another fallacy regarding the micro-macro link in economics is the assumption that causality across different levels only runs in one direction (either ‘top-down’ or ‘bottom-up’), i.e. the hierarchical fallacy. Current mainstream economics follows such a routine by imposing a general “hierarchical stipulation that macro-theories require a microeconomic foundation to obtain full validity” (Rothschild, 1988, p. 14). The economic mainstream thereby emphasizes the ultimate need for reductionist strategies, which aim to explain any aggregate phenomena by ‘summing up’ the behavior and properties of the parts (e.g. Robbins (1932), Lucas (1976), Kydland and Prescott (1977)). Heterodox economists of different persuasions on the other hand argue for a multi-level approach to economic theorizing (e.g. Dopfer, Foster, and Potts (2004), Lee (2011), King (2012)), by emphasizing the changing conditions and constraints for economic action on different levels and the mutual co-existence of top-down and bottom-up mechanisms.

One main reason why such a ‘hierarchical stipulation’ creates more problems than it solves is that in economic contexts emergent properties, not only arise permanently, but also feed back on their constituents, which cannot be assessed within a unidirectional framework. Consider, for example, innovation in market environments and the associated forces of ‘creative destruction’ (Schumpeter, 1942a) and ‘path-dependency’ (David, 1985) or the continuous evolution of social routines (Hodgson & Knudsen, 2004) and consumer preferences (Witt, 2001). In these contexts, where the relationship between individual action and aggregate outcomes is manifold and complex, the epistemological presupposition of a ‘hierarchical stipulation’ of micro over macro acts as a double barrier for understanding. First, assuming that aggregate properties can always be reduced to lower-level entities amounts to committing the static fallacy, that is, to underestimate the dynamics and complexity of social interaction and to turn a blind eye on the unexpected. Second, the related methodological claim that aggregate properties should always be reduced to (current) micro-knowledge, amounts to committing the dogmatic fallacy: the idea that higher-level mechanisms are mere residuals of individual behavior and therefore negligible. Consequentially, they also do not carry any meaningful explanatory role.

In contrast to this assertion stand arguments on causally relevant top-down relationships in economics and elsewhere, which have to be considered in explaining aggregate as well as individual phenomena. We can think of the influence of social norms and regulation on business practices or the social mediation of consumption preferences within a certain community. In the case of the family issues of tradition, power and hierarchy are of vital importance for understanding the ‘private sources’ of women’s deprivation (Drèze & Sen, 1989). The importance

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of such top-down mechanisms in economics has long been emphasized by heterodox economists, some of whom would even claim to inverse the ‘hierarchical stipulation’ inherent in mainstream economics and, conversely, demand a ‘macroeconomic foundation’ for microeconomics (e.g. King (2012)).

One natural example for a heterodox research strategy following this tradition is *stock-flow consistent macroeconomics* (Godley & Lavoie, 2007). Here, one starts with accounting identities and other macroeconomic stylized facts to study macroeconomic dynamics, rather than starting with speculative assumptions about the behavior of a ‘representative household’ (see: Kirman (1992)), as it is common in dynamic stochastic general equilibrium models.

While such a ‘macrofounded’ approach provides an important alternative perspective on macroeconomic dynamics, it is not to be seen as superior to a micro founded approach *per se*. Rather its contribution is to make macroeconomic constraints explicit in modeling, which serves as an important heuristic even when the model is eventually based on microeconomic relationships and assumptions as in so called *agent-based stock-flow consistent models*, that study the economy as a complex system with both bottom-up and top-down effects (e.g. Caiani et al. (2015)). Hence, the merit of taking different levels of analysis as vantage points often lies in the enriching of perspectives on economic phenomena, which heterodox economists practice in a kind of pluralist engagement.

Table 3.1 summarizes the conceptual and methodological pitfalls collected in this section and illustrates the relation between these four fallacies. In what follows we first deal with the question what kind of principles heterodox economists developed to deal with the question of aggregates and aggregation in economics in (section 3.3), before asking whether there exists a general philosophical foundation suitable for summarizing heterodox practice (section 3.4).

### **3.3 A heterodox perspective on the micro-macro link: why the whole is more than the sum of its parts**

One overarching theme in heterodox economic theorizing is the view that the consideration of social wholes is important for the understanding of socio-economic processes and outcomes. This general perspective implies that wholes are more than a mere sum of their parts, since they exhibit non-trivial properties and carry effects of various sorts which cannot be conjectured from looking solely to their constituent parts. However, this idea has also been subject to different specific interpretations and applications within heterodox economics leading to a series of distinct vantage points on the role of aggregates and aggregation in economics: some scholars focus on the explanatory role of top-down mechanisms. Others try to escape the simplistic fallacy by building particularly sophisticated microfounded models. But all of them are united in treating the micro-macro link as a complex relationship that deserves theoretical attention because social and economic aggregates may constitute novel objects or, at least, come with novel features,

	<b>Main error</b>	<b>Fallacious routine</b>	<b>Underlying misconception</b>
<b>The simplistic fallacy</b>	Ignoring relations, i.e. underestimating the complexity of aggregation	Simply summing up individual properties	Wrong treatment of aggregation: <i>“the whole is nothing more than the sum of its parts.”</i>
<b>The static fallacy</b>	Ignoring the possibility of explainable novelties / irreducible properties	Any aggregate property can be reduced	
<b>The dogmatic fallacy</b>	Ignoring that higher-level mechanisms can be studied on their own	Always aim at providing bottom-up explanations	Treatment of aggregates: <i>“wholes cannot be explanatory - they do not carry mechanisms.”</i>
<b>The hierarchical fallacy</b>	Ignoring the possibility of downward causation	Never provide top-down explanations	

Table 3.1: An overview over the various fallacies of composition.



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which may have specific real-world consequences. We now turn four fundamental perspectives that have played a decisive role in heterodox treatments of the micro-macro link.

#### 3.3.1 The whole is more than the sum of its parts

One main implication of the idea that wholes do make a difference is to consider the spatial and temporal variance of social configurations in order to identify distinct realms of economic activity. Such distinctions may refer to historical differences (e.g. ‘medieval feudalism’ vs. ‘20th century welfare state capitalism’), spatial variations (e.g. ‘core’ and ‘periphery’) or distinct spheres of economic activities (e.g. ‘competitive market societies’ vs. ‘subsistence communities’). These distinctions are deemed important since the course and effects of economic activity depend on their social and historical circumstances.

Such differentiations are often found in classical political economy. Consider, for instance, John Stuart Mill’s distinction between the sphere of production and the sphere of distribution. For Mill the decisive difference between these two economic realms is that while the former is constrained by nature, the latter is shaped by human institutions solely (Mill, 1848, pp. II.1.1-2). Consequently, different laws and assumptions apply in these contexts.

Humankind is clearly subject to ‘macrofoundations’ in the form of environmental, historical and societal forces in this account, simply because nature, culture and society as well as the stage of historical developments largely define the constraints and modes of economic activity. In this regard many heterodox economists argue that holistic factors, like culture or institutions, are important for explaining social phenomena and allow for top-down effects or downward causation within their economic theorizing. In a bold, and possibly overarching, interpretation this view may be extended to the claim that social and economic conditions completely determine actions, fate and feelings of individuals. Such a view of socio-economic determinism is often associated with Marx’ concept of historical materialism, although such an interpretation presumably does not do justice to the original Marxian account.<sup>1</sup> In a more modest version such an approach is similar to the approach of a physician, who studies the behavior of a single element (e.g. the behavior of a comet entering the solar system or the pressure in some gas-container in a lab) by taking a full account of the surrounding system (e.g. the composition of the solar system or the size of the container) to correctly anticipate the impact of the latter (Andersen, Emmeche, Finnemann, & Christiansen, 2000). This more modest attitude is key for understanding a variety of heterodox ideas – from ecological economists’ emphasis on absolute constraints (Georgescu-Roegen, 1971) to Keynes personal statements on economic methodology (Keynes, 1938).

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<sup>1</sup>A more accurate account of the relation between structure and agency in Marx can be based on Marx’ claim that „men make their own history, but they do not make it as they please; they do not make it under circumstances chosen by themselves, but under circumstances directly encountered, given and transmitted from the past” (Marx, 1852, p. 15).

### 3.3.2 Relations matter

A second application of the general idea that social wholes make a difference focuses on the interrelatedness of individuals. Attention is devoted to the relations between individuals and the corresponding impact of other people's attitudes and behavior on an individual's economic thought and action.

Interactions among agents as well as between structure and agency are of prime interest to heterodox economists: the analysis of interactions and relations across individual agents and guides studies on preference formation in the context of social emulation (following Marx (1849) or Veblen (1898)), the emergence of routines in organizations (Nelson & Winter, 1982), question of social identity (Fineman, 2005), or the evolution of cooperation (Axelrod, 1984; Bowles & Gintis, 2011). Such a perspective naturally takes relations seriously and allows for agents of different weight – different influence and power so to say – and thereby serves a guide for theorizing on self-reinforcing effects (Merton, 2011), path dependency (David, 1985; Arthur, 1989), wealth concentration, power structures and elites (Rothschild, 1971) as well as other forms of cumulative advantage (Myrdal, 1973). One immediate implication of this reasoning is the conceptualization of an economy as a circular flow, where one person's expenditure adds to another person's income. This view considers monetary transactions as fundamental interactions constituting mutual interdependencies among single economic actors. The consequences of these interdependencies are a major theme in heterodox economics.

Additionally this focus on the role of relations complements our argument that social wholes play an important role, by answering the question of how exactly social wholes come into being. A key idea in this context is to avoid the simplistic fallacy by understanding social wholes as constituted by a set of individual nodes and their corresponding relational setup.

Thereby, social relations play a twofold role. First, they serve as a transmission belt for cultural norms, institutional conventions, established hierarchies or shared goals and aspirations within a social whole. Second, relations serve as means for understanding how individual action might influence social wholes and, hence, provide a lens for assessing social change and novelty.

The role of social relations as a transmission belt features prominently in heterodox economic thought and can be traced back to Karl Marx, who speaks of individuals as an “ensemble of the social relations” (Marx & Engels, 1845), Thorstein Veblen, who emphasized the social formation of consumer preferences (Veblen, 1898) or Karl Polanyi, who coined the term ‘embeddedness’, which emphasizes that individual economic action is always embedded in a certain socio-historical context (Pareto, 1944). From a dynamic perspective this view can also be used to analyze questions of social mobility, where relational structures serve as a means for preserving social hierarchies as in Bowles and Gintis (1975) or Bourdieu (1994), who studied the role of

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educational systems for stratification in the USA and France.

The second major feature of social relations, which allows active agents to influence aggregate properties, also has a prominent role in heterodox thinking and is exemplified by conceptions such as Schumpeter's entrepreneur (Schumpeter, 1942b) and/or Keynes's animal spirits (Keynes, 1997[1936]), who both emphasize that some individual decisions are of great impact for future developments. Against this backdrop it comes as no surprise that active agency plays an important role in heterodox approaches to economic cooperation and trust, institutional design as well as path creation and path dependence (e.g. Hirschman (1970)).

This dual character of social relations which allow for top-down as well as bottom-up effects and thereby captures the fact that individual agents and social structure are mutually interdependent was most explicitly taken up by Mark Granovetter, who refined the concept of embeddedness (Granovetter, 1985). Granovetter distinguished between an oversocialized and an undersocialized conception of individuals, where the latter is attributed to neoclassical and new institutional economics, while the former can be found in purely holistic approaches to social and economic analysis.

Both conceptions eventually posit an atomistic conception of individuals devoid of any relational embedding. For the over-socialized individuals, action has already been completely determined by social forces as a whole and quite independently of any specific relational setup, while under-socialized individuals do not have any significant relations to others. Granovetter sees the embeddedness perspective as a conceptual alternative, where

“[a]ctors do not behave or decide as atoms outside a social context, nor do they adhere slavishly to a script written for them by the particular intersection of social categories that they happen to occupy. Their attempts at purposive action are instead embedded in concrete, ongoing systems of social relations.” (Granovetter, 1985, p. 487).

In this view issues of trust and sympathy affect all interpersonal relations, even in situations where a relation is only initially constituted as a pure economic relation of exchange. The economic implications of this reasoning are non-trivial: they concern industrial structure, trust levels and bargaining processes as well as the level of economic performance. A classic example is given by the high-tech sector, where clusters of coordination and cooperation are particularly common. These clusters are characterized by regular interactions among the involved suppliers, developers and customers, which leads to a quasi-integration of different steps throughout the supply chain, although these steps are carried out by formally independent organizations. The longer such relations exist, the more do they 'outgrow' the market and become insensitive against market signals such as 'prices' (Elsner, Heinrich, & Schwardt, 2014).

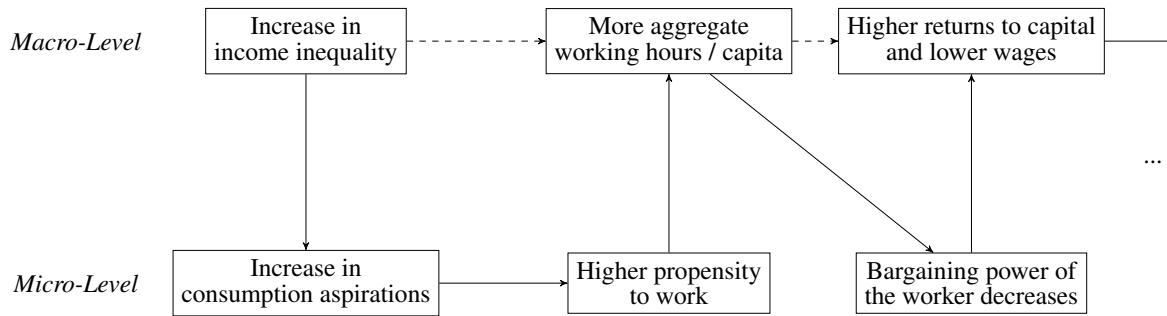


Figure 3.1: Three different ideal types of networks.

But Granovetter (1985) stresses that social embeddedness is not only a source for trust, stability and cooperation, but also for exploitation, disorder and conflict. Hence, Granovetter’s approach does not allow for general predictions aside from the claim that “network structures matter”, since outcomes eventually depend on the overall network structure. Whether, for example, a system is vulnerable to particular interest groups, who work against general interests thereby depleting stability and trust, depends on the concrete case at hand.

In standard economic accounts such structural properties largely remain implicit: for instance, most Walrasian general equilibrium models do not account for networks explicitly, but assume implicitly the system to be structured as a bipartite star network, as illustrated in figure 3.1(a). In this setup agents are not directly related to each other, but rather connected indirectly via a central auctioneer, who has direct relationships with all agents and, hence, resides in the network’s center. A change of the network structure has non-trivial effects: an otherwise identical model economy characterized by a ring network figure 3.1(b)) exhibits very different distributional characteristics and price patterns than the star network, implicit in the conventional Arrow-Debreu economy (Albin & Foley, 1992).

Real networks are, of course, neither rings nor stars: network analysis has made impressive progress since the 1990s and found that most empirical networks look in some ways similar to figure 3.1(c): there are few nodes with many connections, and many nodes with few connections. Furthermore, nodes are organized into different clusters.<sup>2</sup> To explore the economic implications of this structure is an important avenue for future research.

But can we make reasonable predictions about the meso or macro level of the economy, given a precise description of the micro components as well as their relations? Notwithstanding the obvious merits of such an approach, the next section explains why a general affirmative answer

<sup>2</sup>Many statistics are available for the description of complex networks, and one should definitely be more precise than the space of this book chapter allows. See Newman (2003) for a nice introduction considering most recent advances in the literature.

to this question cannot be provided.

### 3.3.3 There is real novelty

Another aspect of a heterodox perspective on the micro-macro link, which is strongly intertwined with claiming the importance of incorporating relations into social and economic analysis, is the notion that novel objects or properties constantly arise in the course of social interaction. This specific aspect of social wholes – the fact they are carriers and transmitters of genuine novelty – is at the heart of this subsection.

Economic systems regularly produce novel features that are not predictable from past data. The emergence of novelty can be most intuitively illustrated for the case of innovation, which was a key element in the work of Joseph A. Schumpeter. Schumpeter distinguished between five types of innovation (Schumpeter, 1942b, p. 66), such as the development of a new good, the introduction of products of higher quality, or alternative methods of production.

All these kind of innovations represent or bring forth novelties that have not been existent in an economic system before. They may carry new mechanisms that fundamentally change the functioning of the economic system as a whole: the advent of globalization, for example, not only came with cheaper import goods, but also introduced a new mechanism – the race for national competitiveness – which puts different countries in a competition for serving the interests of powerful transnational corporations. The invention of digital computers, to give another example, led to new markets, new types of goods, and even new life styles that continue to influence our society via novel mechanisms in various ways. While innovations can often be understood as a creative recombination of already existing ideas, neither the exact way of recombination nor its consequences for society are *a priori* predictable.

This fact motivated heterodox economists to further elaborate on the micro-macro link to gain a deeper understanding of this non-predictability. One main pillar in this context is development of arguments on fundamental uncertainty in economic action which focuses on the role of crucial decisions in investment, whose effects are very hard or impossible to anticipate. These circumstances give scope to alternative economic motives beyond conventional utility maximization such as routines and rules, individual vision and passion (as in Schumpeter's entrepreneur) or inherited instincts (as in Veblen's *instinct of workmanship*).

Another venue of work in this context aims for a refined conception of 'meso' in economic analysis (Dopfer et al., 2004; Elsner & Schwardt, 2014). Proponents argue for a 'micro-meso-macro' framework as a substitute for the conventional micro-macro dichotomy. In such a framework the economic agents represent the micro level of the economy and are heterogeneous as they carry different rules. A rule and all its actualizations constitute a meso unit, which is

seen as a key element in evolutionary economic investigation, since the interaction of rules is understood as a main driver of economic change on the macro level. Assume, for instance, that creditors and debtors in a given economy mutually adapt their crediting and borrowing behavior to each other. In such a setup increased risk-taking on the side of creditors, who are prone to forget or ignore past turbulences, would be mirrored by increased borrowing by debtors leading to potentially unsustainable levels of debt. Hence, we can reach the classic Minskyan result that “stability breeds instability” (Minsky, 1986) by employing a simple model of rule convergence on credit markets.

The obvious advantage of such an analytical framework is that it allows focusing on economic change and thus understanding the source of the unpredictability of real novelty within the economy: One more specific expression of this rather general claim is provided by the theory on path dependence, originating from the seminal papers of David (1985) and Arthur (1989) dealing with technological lock-in. Generically, we can disentangle path dependent processes into three different phases (Sydow, Schreyögg, & Koch, 2009; Dobusch & Kapeller, 2013, 3):

The first phase, path creation, characterizes a situation of contingency. Events happening at this stage are usually “outside the ex-ante knowledge of the observer” (Arthur, 1989). They are nevertheless important because these events characterize the initial conditions for the second phase, where an ergodic dynamic process, characterized by positive feedback effects and subsequent, causally linked events, leads to the dominance of one particular standard. The positive feedback may stem from different forms of network effects based on increasing returns, preferential attachment, learning and coordination effects, complementarity requirement or the convergence of expectations. The last phase, the resulting lock-in, then reflects the resilience of the dominating standard against change. Thus, while it is almost impossible to predict the diffusion process ex ante, it only becomes possible to identify the dominant technology after one has entered the second phase of the path dependent process.

Hence, path-dependency theory focuses on the mechanisms underlying the introduction of novelties and the creation and persistence of social standards of different forms (like social norms, organizational rules, business practices and technological requirements, etc.). In doing so it provides a theoretical rationale for the emergence of novelties and explicates the difficulties in predicting such novelties. At the same time path-dependency theory is silent on the effects brought forth by such novelties, which often represent controversial questions in heterodox economics. A prime example is given by the effect of the adoption and diffusion of new innovations on the level of employment: while some innovations indeed function as labor-saving devices (as in the standard Keynesian approach), others may increase employment due the creation of additional demand induced by novel products or improvements in product-quality and versatility (as in the Schumpeterian approach, e.g. Witt (2001)). Which effect eventually dominates in the face of general technological progress or a specific innovation is, hence, a question which can be

hardly answered *ex ante*.

These arguments imply that *ex ante* predictions are often difficult or impossible, since the emergence and effects of novelties can hardly be fully anticipated. Nevertheless, the relevant trajectory can of course be explained *ex post*: We understand well how a specific successful innovation diffused into society and how it affects their members.

### **3.3.4 Aggregation and welfare**

Finally, our forth perspective on social wholes and their role in economic theorizing relates to the normative question of economic welfare in the context of aggregation. Mandeville (1714) advanced the view that ‘private vice’ in the form of egocentric instrumental rationality will lead to ‘public benefits’, that is the maximization of social welfare. This view is deeply inscribed in modern mainstream economics, especially in the two fundamental theorems of welfare economics. While many heterodox economists surely would accept, that the Mandeville-case is indeed a possible state of affairs, they also tend to critically examine the conditions required for the Mandeville-case to prevail. Classical examples in this context include rationality traps – “if I can improve my view in the theater by standing up, will there also be a collective improvement if everyone follows this rationale?” – or references to the “tragedy of the commons” (Hardin, 1968) which describes the unsustainable usage a public good in the absence of a suitable mode of social coordination (Ostrom, 1990). More formally, such cases can be expressed in the form of a prisoner’s dilemma, which illustrates the core property of rationality traps and tragedies of the commons, namely that myopic individually rational actions will lead to the worst possible aggregate outcome. This relationship is the main reason why some heterodox economists consider a prisoner’s dilemma as one archetype for heterodox economic modeling (Elsner et al., 2014). Since the welfare aspects of social organization are a general topos of heterodox economic theorizing, we find variants of this argument in several heterodox traditions: ecological economists emphasis on collective good problems (e.g. climate change), Marxian perspectives on power and conflict and evolutionary as well as institutional economists’ focus on the role of social norms, conventions and law in resolving social dilemmata.

## **3.4 Systemism as a general framework**

### **3.4.1 Systemism and heterodoxy**

While the concept of systemism might seem new, one can be assured that the practice of systemism is far from something completely novel. We introduce the concept of systemism to provide a full-fledged philosophical concept, which encompasses the basic heterodox arguments on the micro-macro link in economics. The development of systemism owes mainly to the

works of Mario Bunge, philosopher and polymath, who aimed to transgress the traditional dichotomy between individualism and holism, which he perceived as an outdated hindrance to social research and epistemological debate.

Bunge cites a variety of examples for what he conceives as a ‘systemist’ social research. Interestingly, within these passages the names of heterodox economists come in definitely non-random abundance: Among others Bunge mentions John Maynard Keynes and Wassily Leontief (Bunge, 2004, p. 187), Max Weber, Joseph A. Schumpeter, Thorstein B. Veblen or K. William Kapp (Bunge, 1979, p. 92-93). More recent examples for heterodox approaches compatible to a systemist perspective are supplied by an understanding of economics as the study of the social provisioning process (Jo, 2011) or the postulate of evolutionary economists to focus on the meso-level of economic activity (e.g. Dopfer et al. (2004)). In sum, these observations suggest that heterodox economic approaches serve as salient candidates for illustrating a systemist approach to social and economic issues and, conversely, systemism serves as a natural candidate for epistemologically substantiating heterodox economic research.

### **3.4.2 Systemism: key ideas and concepts**

Systemism is built upon the fundamental twin concept of systems and mechanisms, where the latter are situated within or between the former. Thereby any object or entity in systemist analysis is considered either as a system itself or as a component of a system (Bunge, 1996).

A system is composed by a set of nodes or components (its composition) with a particular relational setup (a system’s structure or organization) situated within a certain environment. The interrelatedness of agents not only contributes to the constitution of a specific system, but gives rise to a variety of ‘ontological novelties’, i.e. some features that the whole possess, but its components lack (global properties, like a nation’s culture or a firm’s success) or some features components acquire exactly because they are part of some system (relational properties, like being a creditor, a wife, or an employee; see Bunge (1996)). The concept of a system can therefore be applied on several levels: a family is a system consisting of different members with particular relations to each other. At the same time it is a part of a community system where it has several relations to other components of the community. The resulting levels of the system take the form of a hierarchy of sub- and super-systems which serves as a basic ontological framework. Such a hierarchical understanding of reality has been insinuated by several heterodox approaches, in particular in the work of Herbert Simon, who gave an evolutionary explanation for the predominance of hierarchy in the complex systems of reality (Simon, 1962).

The second fundamental ingredient to systemism are mechanisms: they are essential because systemist theory aims for mechanism-based (or mechanistic) explanations of phenomena (Bunge, 1997). Mechanisms work within or across social systems and lead to continuous changes and stabilization of a given system. This is why we conceive of them “as a process (or sequence



of states) in a concrete system, natural or social” (Bunge, 2004, p. 186). Thereby three rough types of mechanisms can be distinguished: first, within-level mechanisms operate within social systems, but address only one ontological layer (e.g. a reduction in hourly income may induce a household to increase working hours). Second, bridging mechanisms also work within a certain social system and can take the form of agency-structure relations (i.e. a bottom-up mechanism or upward causation) or structure-agency relations (i.e. top-down mechanisms or downward causation). The former provide a theoretical alternative for the aggregation of individual behavior going beyond a mere ‘summing up’ of individual properties, by employing theoretical mechanisms for means of aggregation. Possible examples for such ‘bridging mechanisms’ are bandwagon effects, where final outcomes depend on the sequence of individual moves, positive feedback effects, which may lead to path-dependent properties of social systems or emulation effects, where individual behavior conforms to or is constrained by the behavior of others (as in the case of rationality traps). Finally, there are mechanisms operating between a system and its environment (i.e. overlapping and surrounding systems), like imitation of technologies or competition among firms. One example of a heterodox approach integrating all these relevant processes is the agent-based stock-flow consistent model mentioned above: it is an excellent example of truly systemist research that aims to transcend both, purely individualist and holist approaches.

This focus on concrete mechanisms in systemist epistemology aims to refine the standard model of scientific explanation by emphasizing the importance of uncovering the generative mechanisms underlying empirical relationships instead of simply collecting and applying these relationships: to explain the death of a person with their property of being human, and the fact that all humans eventually die, is not very insightful; rather we should try to identify the concrete mechanisms that have led to the state of affairs to eventually arrive at more general theories (Bunge, 1997, p. 425).<sup>3</sup>

Note that systemism is not a theory, but rather an ontological and epistemological heuristic, like “a viewpoint, or a strategy for designing research projects whose aim is to discover some of the features of systems of a particular kind” (Bunge, 2004, p. 191). Considering this fact and the fundamental aspects of systemist models, we claim that systemism is a well-suited philosophical framework to structure heterodox theorizing on the micro-macro link as outlined above. Based on these considerations we can now try to explore the relation between heterodox economic arguments and the systemic framework.

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<sup>3</sup>Note that Bunge (1997) uses this argument not only to question the conventional covering law model, but also to criticize other concepts, like hermeneutics or Occam’s razor, which neglect the main task to bring forth new and testable hypotheses.

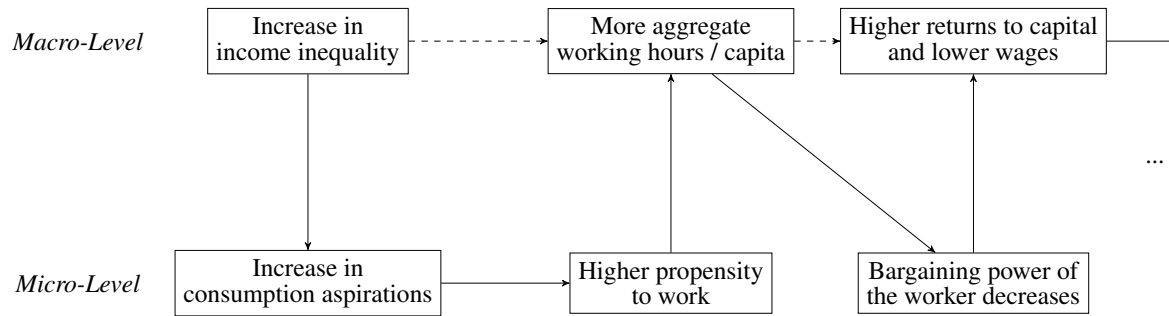


Figure 3.2: The relationship between rising inequality and increasing working hours as suggested by Bowles and Park (2005)

### 3.4.3 Heterodox economics in a systemist framework

Bunge's concept of systemism does not only provide a suitable philosophical framework for heterodox theorizing on the micro-macro link, but also offers an intuitive way to express and conceptualize theoretical considerations of micro-macro interactions. The following examples illustrate this aspect from a practical perspective.

The first illustration is provided by Bowles and Park (2005), who use the Veblenian concept of social emulation to explain the allegedly counterintuitive relationship between rising inequality and increasing working hours (figure 3.2). Due to social emulation of preferences a higher level of income inequality induces an increase in consumption aspirations across households. In order to live up to these aspirations a (sizeable) subset of these households increase their working effort, which leads to an increase average working hours. A possible extension of this argument would argue that this increase in the supply of labor reduces the bargaining power of workers and, hence, leads to lower wages, with further increasing income inequality leading to a path-dependent downward spiral.

Our second example considers the emergence and evolution of social conventions Hodgson and Knudsen (2004) discuss an agent-based model, where drivers are forced to decide whether to drive on the left or on the right side of a street. They study the conditions required to guarantee the emergence of a stable convention. While their major finding is that habit-formation is a probable vantage point for the emergence of conventions, the illustration in figure 3.3 extends the underlying argument by illustrating the emergence of conventions in a systemist framework considering both bottom-up and top-down effects.

These examples show that what Bunge's concept of systemism offers is far away from a methodological straight-jacket. Quite on the contrary, the schematic approach utilized in these examples aims at illustrating how this approach can be employed to facilitate conceptual thinking and the crafting of ontologically sensible theoretical frameworks on the basis of a solid epistemological foundation. It further provides a useful meta-language that enables the effective comparison of different theories of the micro-macro link in heterodox economics and to exploit the potential complementarities among these different approaches (see also: Dobusch

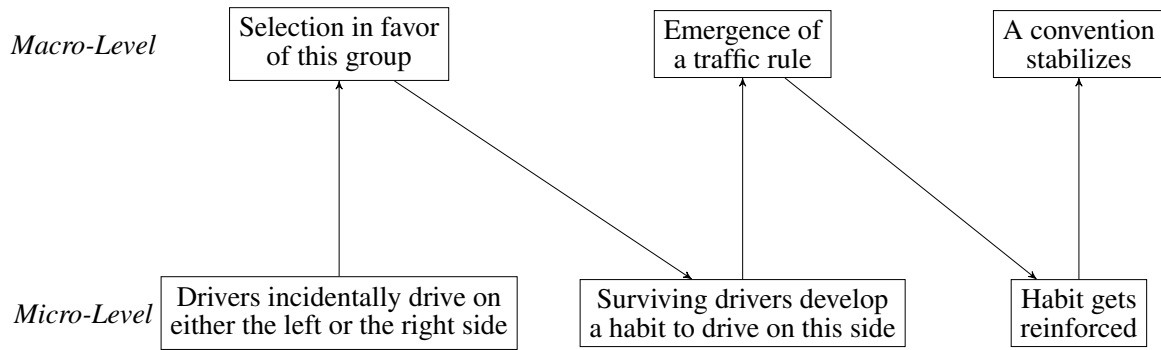


Figure 3.3: The up- and downward effects underlying the emergence of a social rule (Hodgson & Knudsen, 2004).

and Kapeller (2012, 4)).

### 3.5 Conclusion

The complex relationship between different ontological levels has received considerable attention in heterodox theorizing. This has led to the development of a number of important independent contributions to the role of aggregates and the issue of aggregation in social research, which often allowed heterodox economists to circumvent typical fallacies of aggregation identified in this chapter.

In this chapter we aim to show that the central pillars of different heterodox conceptions of the micro-macro link are not only complementary, but can also be subsumed under a common philosophical umbrella labeled ‘systemism’. This umbrella is a useful device helping to explore the commonalities and differences in various heterodox approaches to the micro-macro link in economics. In many cases such comparisons will facilitate a ‘heterodox convergence’, as in the case of evolutionary-institutional and social economics (Elsner, 2014), while in other cases the relationship may take the form of productive disagreement. Such a productive endeavor requires a common denominator for the different approaches enabling mutual communication and comparability. We argue this missing component is exactly what systemism can supply.

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## Chapter 4

# Agent-Based computational models - A formal heuristic for institutionalist pattern modelling?

### Chapter Abstract

I investigate the consistency of agent-based computational models with the institutionalist research program as outlined by Myrdal, Wilber and Harrison, Hodgson and others. In particular, I discuss whether such models can be a useful heuristic for “pattern modelling”: Can they provide a holistic, systemic and evolutionary perspective on the economy? How can agency be conceptualized within ABMs? Building on these issues, I discuss potentials and challenges of the application of ABM in institutionalist research. This discussion also relates to recent methodological advances in neo-Schumpeterian economics. I explain how institutionalists can benefit from these and suggest areas of research for joint work under the methodological umbrella of ABM.

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## 4.1 Introduction

Institutionalists have always been criticizing the neoclassical way of modelling the economy, especially because of its obsession to a strict formalism. On the other hand, there have been a number of attempts to introduce more formal modelling tools to institutionalist economics, including the social fabric matrix (Hayden, 1982), system dynamics (Radzicki, 1988) and evolutionary game theory (Elsner, 2012). In this article I discuss whether agent based computational models (ABM)<sup>1</sup> can provide a useful formal extension to the research program of original institutional economics (OIE).<sup>2</sup>

ABMs are commonly associated with the rising research program of complexity economics.<sup>3</sup> While some consider complexity economics to be an interesting extension to neoclassical economics (e.g. Blume and Durlauf (2006)), others consider it to represent a completely new way of thinking about economics Arthur (2006) and criticize the “analytical straitjacket” of neoclassical economics from a complexity perspective (e.g. Farmer (2012)). The relation between OIE and complexity economics is largely unexplored. Many concepts of complexity economics, though, have been anticipated by institutionalists: Although using a different vocabulary, complexity economists speak about cumulative causation, dynamic relations among individuals and an organic, rather than atomistic, view on the economy. Consequently, ABMs should not be left unconsidered by institutionalist economists. The study of whether ABMs can be a useful tool for institutionalist research may also hint at potential convergences of institutionalist and complexity economics.

This paper contributes to this question by investigating whether the use of ABMs is consistent with the research program of OIE as it was outlined by Myrdal (1978), Wilber and Harrison (1978) and Hodgson (1988). These works are still representative for a considerable part of OIE. But they do not capture some recent developments in the field:

Firstly, within the OIE, there are strong voices criticizing the development towards behaviourism and empiricism, and argue for a stronger orientation towards Darwinism. How exactly Darwinian principles should play a role in economic theory is subject to an ongoing dispute. I will reflect on the methodological implications of this dispute to the extent it is relevant to assess the role of ABM in OIE later in this paper.

Secondly, looking for more recent advances in institutionalist methodology leads to the

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<sup>1</sup>Numerous acronyms exist and most denote synonyms, e.g. ABM, ABMS or IBM. Others, such as ACE (agent based computational economics) accentuate that not only the model, but also the means to solve it and analyse the outcomes are crucial. While I have much sympathy for this idea, I here stick to the most common acronym, ABM.

<sup>2</sup>While ABMs are usually written in computer code, they can, in theory, always be expressed via mathematical equations. This is due to the famous Church-Turing thesis, which is at the heart of modern computer science and recursion theory. ABMs are thus to be considered formal models. Within institutionalist economics, formal models have always been handled with great care. I therefore emphasize that ABMs can never be self-explanatory but can only be considered a heuristic, or a tool.

<sup>3</sup>Although not all complexity economists agree to the use of ABMs, see e.g. Durlauf (2005).

question about the relation of OIE with modern evolutionary, or neo-Schumpeterian, economics. Several important methodological contributions were made by this research community. Although it shares important origins with OIE, the two research orientations diverged significantly in the past century. Neo-Schumpeterian economics took off with the seminal contribution of Nelson and Winter (1982) and put economic dynamics and technological change at centre stage of its analysis, with formal methodology playing a bigger role than in institutionalism. Throughout this paper I will make several references to these contributions that carry important methodological reflections from which many institutionalists can benefit. I will also question how ABMs might help to motivate joint research and a stronger convergence of the programs, as advocated for by e.g. Hodgson and Stoelhorst (2014, 04).

The rest of this paper is structured as follows: After giving a short introduction to ABM in Section 2, I will study the compatibility of ABMs with key aspects of institutionalist modelling in Section 3. Then main potentials and dangers of ABM are discussed in Section 4. Section 5 concludes and points to directions for future research.

## **4.2 What Agent-Based computational models are about**

ABMs are expressed via a programming language and help to understand how individual actions lead to patterns, how these patterns in turn shape individual behavior and what dynamics result from this interplay on the level of the societal system as a whole.

ABMs differ from the strict analytical framework of conventional economics as the modeller is not forced to make assumptions in such a way that an equilibrium path results in the model. They allow a realistic and dynamic representation of the system under investigation in the sense of an evolutionary science (Veblen, 1898).

The basic idea is to specify the fundamental entities (esp. the economic agents and their relations) in an adequate manner, and to study the systemic and dynamic consequences of this configuration. Because the resulting system usually is not tractable analytically, one relies on numerical simulation to solve it. This means to proceed from the assumptions about the system to the conclusions regarding its overall dynamics. This contrasts the practice in general equilibrium modelling (esp. Computable and Dynamic Stochastic General Equilibrium modelling): While these models are said to be microfounded, one has to specify the assumptions on the micro level not solely based on their adequateness, but in such a way that they stay mathematically tractable and are suitable to yield a stable equilibrium path. While the equilibrium is formally a conclusion of the model, it should be seen as an implicit macro assumption that dominates the micro assumptions of these models.

ABMs on the other hand can be evaluated on all levels: The model agents, for example, can

be subject to microcalibration. This involves a direct test of the adequateness of the agent design. Thanks to the specification of the agents via computer code, there is no upper limit for the complexity of the rules other than accountability considerations (Chen (2012), see also Section 3.4). More generally, ABMs allow heterogeneous and boundedly rational agents in the sense of Herbert Simon (rather than in the sense of modern behavioural economics) that are not atomistic, but directly interdependent and socially embedded (Granovetter, 1985). The embeddedness is modelled via an underlying, possibly dynamic, graph. Such a graph could represent a simple grid or an (potentially empirical) interaction structure among the agents. Agents can also be capable of communicating with each other and of hiding or sharing information (Moss, 2002).

Technically, agents are instantiated as a digital object that has attributes and different rules (called ‘methods’) according to which these attributes change. Such a specification of the agents allows the natural implementation of heuristics, learning and habits through the methods. As each agent is a distinct digital object, one can consider situations of true uncertainty directly without transforming uncertainty into risk (Pyka & Fagiolo, 2007).

ABMs also allow the natural inclusion of institutions, rules and networks. These phenomena are often subsumed under the meso level of the economy, because they affect an emerging subset of the whole population (Elsner & Heinrich, 2009).<sup>4</sup>

ABMs can include these phenomena as the methods of the agents use not only the current state of the agent itself as an input, but may also consider the states of her neighbors, a group of agents or the state of the system as a whole. It is therefore straightforward to study phenomena such as reconstitutive downward effects in ABMs. Let us look at an example:

Throughout this article I will use the model of Hodgson and Knudsen (2004) as an illustration for the usefulness of ABM. The authors study the emergence and evolution of a simple traffic convention.<sup>5</sup> In their model, agents drive cars on a ring structure, half of them clockwise, the other half anti-clockwise. Every round, each driver has to decide whether she wants to drive on the right or the left.

The authors clarify that the experimentation with different decision rules in their model helped them to identify a surprisingly easy, but very effective decision procedure (Hodgson & Knudsen, 2004): Drivers develop a habituation of driving either on the left or right side and the model shows how the presence of habituation fosters a convergence to a drive-left or drive-right

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<sup>4</sup>Such a notion of “meso” is slightly different to what meso means in the “micro-meso-macro” framework of Dopfer, Foster, and Potts (2004), where a meso unit is a social rule and all its actualizations. But this notion of meso can also be implemented in an ABM. (Dopfer & Potts, 2004, p. 211) even use an analogy of object oriented programming, the dominating programming approach for ABMs, to illustrate the ontology underlying their analytical concept of “micro-meso-macro.”

<sup>5</sup>Throughout the article I will use a simple definition of emergence: An emergent property is considered a property of either the system as a whole or of a set of several parts of the system taken together that cannot be observed for or derived of the single constituent parts of the system alone - for either epistemological or ontological reasons. See Kim (2006) for an introduction and Harper and Lewis (2012) for an illuminating introduction to a special issue on this subject.

convention. The model also shows that habit formation is not the only relevant mechanism, but that a combination of mechanisms leads to the emergence of the convention. Due to the modular structure of their ABM, the authors were also able to study what happens if habit is substituted by pure inertia, and that the functioning of institutions is best interpreted as influencing habits rather than behaviour or preferences. This shows how ABMs can be used to study different mechanism and their mutual influences on each other in one coherent model. It also illustrates how ABM can serve as an analytical mean within a layered ontology.

It is an interesting consequence of the generality of the agent-based approach that it contains the formal models of neoclassical economics as one particular special case. It is also worth noting that ABMs are well established in many sciences outside economics, e.g. urban planning, epidemiology, logistics or ecology. In evolutionary economics, after the important contributions of Potts (2000) and Pyka and Fagiolo (2007), it is now an established tool to study technological change.

### **4.3 ABMs and the methodology of OIE**

It is not straightforward to identify the methodological core of the vital and pluralistic research program of OIE. A very good starting point is the classical paper of Myrdal (1978) under the heading “Institutional Economics”. In the same year, Wilber and Harrison (1978) characterized the institutionalist way of modelling as pattern modelling and came to very similar answers as Myrdal (1978). The criteria identified by the authors are still representative for a large part of original institutionalists work and serve as a vantage point for the question of whether ABMs can play a role in institutionalist economics today.

Five main criteria can be identified from their work: institutionalist models are necessarily holistic, systemic, pay particular attention to relations within a society, are evolutionary and based on a realistic conception of economic agency. I will now scrutinize these points one by one. Thereafter, I consider the more recent methodological trends that were identified in the introduction.

#### **4.3.1 Holism: The relevance of downward effects**

Wilber and Harrison (1978) explicitly distinguished between holism and systemism. Holism is considered to be the opposite of atomism and entails a focus on the pattern of relations among the agents and the economy as a whole (Wilber & Harrison, 1978, p. 71). This expresses the belief that the whole is not only greater than the sum of its parts, “but that the parts are so related that their functioning is conditioned by their interrelations” (Wilber & Harrison, 1978, p. 71). Here it is important to distinguish among ontological and epistemological holism: If holism has

an ontological meaning, the study of agency, individual incentives and the relation among the parts making up the whole becomes unnecessary. Such a view must not be compatible with institutionalist theory. Institutionalists have always stressed the learning capacities of individuals, the variety of reasons guiding their decision making, their instincts and their idle curiosity. Such concepts are worthless to the ontological holist as they would be mere derivatives of the social structure in which the individuals exist. More adequately, holism is understood in the epistemological sense: In order to understand the behavior of individuals, a deep understanding of the social structure into which they are embedded is required. This is what Wilber and Harrison mean when they argue that the process of social change is the product of human action, which itself is shaped and limited by the societal structures it is embedded into. While their distinction to systemism is not clear, their use of the concept of holism suggests that both the relations among individuals and the relation between different ontological levels of the economy are important.

This idea is most precisely developed in the institutionalist concept of reconstitutive downward effects (Hodgson, 2002, 2006, 2011): individuals, groups and the entire population are strongly interconnected and patterns emerge because of this interconnectedness of different ontological levels. These emergent patterns then shape the consciousness and behaviour of the agents on the individual level again. They are independent of the support of the single agent but can only be sustained if they are supported by a critical mass of agents. Because these effects arise from the action on the lower micro level, but these actions are influenced by the effects themselves, they are called reconstitutive downward effects. Following the current conventions, a theory considering reconstitutive downward effects would not be termed holistic, but systemic. (Wilber & Harrison, 1978) made use of the term holism probably as a differentiation to neoclassical individualism. But individualism “is also rejected by systemism alone” (Bunge, 2000).

Can ABMs be consistent with a view of the economy that stresses the mutual interdependence of its different layers? Brian Arthur, a leading figure of the complexity movement in economics and an advocate of ABMs, described them as models in which “[b]ehaviour creates pattern; and pattern in turn influences behavior” (Arthur, 2006, p. 1553). This is the same as to say that “parts are at once conditioning and conditioned by the whole” (Wilber & Harrison, 1978, p. 80). In an ABM one specifies the agents and how they behave in certain situations. The trigger for their behaviour can be, as explained above, their own state, the state of their direct environment, the state of a certain group or the state of the global system. As other agents, groups and the system as a whole are also influenced by the agent herself, it is straightforward to see how the concept of interdependent levels can be accounted for in ABMs.

One could also deal with a more refined version of such a layered ontology within an ABM: Building on the ontology of evolutionary realism of Dopfer and Potts (2004), Dopfer et al. (2004)

propose a micro-meso-macro framework which puts the diffusion of rules at the centre stage: In their analytical frame, a meso unit is not simply a subset of the whole population, but a rule and all its instantiations in the population of agents. The micro level is represented by the economic agents, who are users and carriers of rules, and the macro level is the interrelation of different rules (deep structure) and the corresponding carrier groups of the rules (surface structure). Here, the technical question of whether either agents or rules or both should be modelled as classes on their own, forces one to be extremely precise on the theoretical level and to elaborate on small but significant differences among different ontological and analytical approaches.

### **4.3.2 Systemism: Organized complexity and self-organization as central properties of social systems**

For Wilber and Harrison (1978, p. 71) systemism meant that “parts (of a system) make up a coherent whole and can be understood only in terms of the whole”. This conception of systemism is now outdated. The idea the authors convey is that the relations among the entities of the system under investigation matter and can lead to ontological novelties (which then may feed back on the related entities, see section 3.1).

This idea is captured by the philosophical framework elaborated by Mario Bunge. For Bunge, systemism means to understand everything as either a system or a part of one. The parts of a system are related in a particular manner, giving rise to emergent properties on higher ontological levels.<sup>6</sup> It is interesting that Bunge uses the work of Veblen, Myrdal and Schumpeter as examples for systemist research and thus points to the strong affinity of OIE and neo-Schumpeterian economics.

But even more importantly for the topic of this paper, there exists a strong theoretical affinity to the conception of complexity of Weaver (1948). His concept of organized complexity is at the heart of complexity economics and suggests a strong complementarity among OIE and complexity economics. Weaver contrasts complex scientific problems from simple ones:

Simple problems include only few variables and were studied by pre-1900 physics and engineering. Problems involving living organisms can never fall into this category: they involve too many different aspects and, because of the interrelatedness of the variables, defy *ceteris paribus* assumptions (Weaver, 1948, p. 537-538).

Weaver then distinguished between problems of organized and disorganized complexity: A system consisting of many components shows disorganized complexity if some emergent pattern exists because the linear interactions between the different elements smooth each other out. The Law of Large Numbers describes such an emergent pattern. Most econometric theory

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<sup>6</sup>For a more detailed exposition of Bunge’s systemism and its usefulness for economists see Kapeller (2015) and Gräbner and Kapeller (2015).

assumes this kind of complexity when it assumes error terms to be identically and independently distributed.

In contrast, a system showing organized complexity exhibits patterns, which emerge because the interactions of the different elements do not smooth each other out (i.e. are non-linear). This is the case if there exists a kind of self-organization of the system such that the factors are interrelated into an organic whole (Weaver, 1948, p. 539). When arguing for the need of systemic models, institutionalists implicitly say that the economy exhibits organised complexity.<sup>7</sup> The analytical models of neoclassical economics presume the economy to show disorganized complexity. Their unambiguous results can only be obtained by assuming mechanical agents that interact in a linear fashion.

Many ABMs are motivated with the argument that the economy exhibits organised complexity (Potts (2000), Miller and Page (2007)). The implementation is straightforward: Heterogeneous agents interact with each other and their environment. As there is no requirement for the system to exhibit any particular dynamic (esp. an equilibrium path), assumptions can be made on entirely proper considerations. One can then conduct artificial experiments by changing an aspect of the model and check whether an emergent pattern is the result of the change or not. One can model the system with an adequate specification without a compulsive formalism, but with the obligation to state any assumed process explicitly.

Again, the model of Hodgson and Knudsen (2004) is an excellent example: the authors have one version of the model with inertia instead of habit and thus can compare the effect of this different decision making algorithm on the overall dynamics. The resulting convention in their model is both dependent from individuals following it, but also influences individual behaviour.

Weaver's definition of organized complexity also suggests to relax or drop assumptions about fictitious central planning mechanisms such as the Walrasian auctioneer, but study the economy as an interactive and self-organizing system without central control. The concept of self-organisation has been discussed by leading scholars of Schumpeterian economics such as Witt (1997) and Foster (2000).

It also plays a role in the discussion about Darwinian principles in economic theory: While some consider self-organisation as an alternative to Darwinian principles (Witt, 1997), others claim that self-organisation is an important mechanism which has to be embedded into a broader Darwinian framework (Hodgson & Knudsen, 2010). No matter whose position is taken, the capacity of a system to organize itself without a central planner is considered to be important and to deserve attention.

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<sup>7</sup>Again, there are important parallels to the micro-meso-macro approach of Dopfer et al. (2004) For them the relation between different rules, rule carriers and populations of rule carriers shape the trajectory of the system.

Practically, this means that one has to deduce the overall dynamics from the interaction of its constituent parts. This is exactly what ABMs were invented for. The next step is to consider the precise structure of the interaction.<sup>8</sup>

### 4.3.3 Social structure and networks

A systemist analysis of the economy requires one to pay attention to the relations within the economy (Bunge, 2004, p. 188). These relations are represented by networks (or graphs). Network science has been a lively area of research and developed both a plausible taxonomy for empirical networks and theories of how these networks could have come into existence.

Institutionalists should build on these insights: For most systems, “structure always affects function” (Strogatz, 2001) , so one should be very precise about this structure. But networks are difficult to describe verbally and the relation between network structure and the economic outcomes is usually not intuitive. In this case ABM are a very strong ally in visualizing the mechanisms underlying real-world dynamics.

Such an application of ABM contrasts the implicit practice of neoclassical economics to assume complete (or trivial) networks, where all agents needs to be the same. This can only be true in trivial (complete or empty) networks. But recent studies of networks showed that small-world or scale-free networks are ubiquitous in reality.<sup>9</sup> Small world networks are characterized by small average path lengths between the nodes and comparatively high degree of clustering.

Roughly speaking, in small world networks the nodes may not interact directly with one another but the number of middlenodes required to connect two randomly chosen nodes is usually small. Additionally, there are groups of nodes that are very closely connected to each other, i.e. where the probability that there is an connection between two group members is extremely high. The constituent feature of scale free networks is that there are very few nodes with a lot of connections to other nodes, and very many nodes with very few connections to other nodes. More precisely, the distribution of the number of neighbours (i.e. the degree of the nodes) follows a power law.

How these networks influence the distributional properties of an economic system can be

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<sup>8</sup>An interesting concept in this context is that of self-organizing criticality. Open systems show self-organized criticality if the system is characterized by a self-organizing process (e.g. the interactions of the agents) that leads to a critical state of the system, i.e. a state of the system that is robust to small changes, but frequently experiences ‘avalanches’ of change, after the changes cumulated in a specific way. For more information on and applications of this concept using ABM see e.g. Moss (2002).

<sup>9</sup>The issue is much more complex than presented here and empirical networks be described using different statistics or the sake of the argument, the following coarse grained description suffices for our purposes. See the excellent (and freely available) introduction to network theory of van Steen (2010) for further details.



studied via ABM. Albin and Foley (1992), for example, considered changing network structures in the general equilibrium framework and showed how a shift from central to de-central organization has severe distributional effects. Their model remained very abstract and one would not classify it as an institutionalist model. They exemplify, however, the huge consequences of a small change in the underlying network structure. This insight is important for institutionalists when describing the stratification of real-world economies, because networks play an important role for the observed stratification (and unequal distribution of wealth).

In order to figure out how this role looks like, one must build on a formal assessment of these network structures, particularly because network structures are a catalysator to other aspects (Page, 2012). To have these results in mind is important for the construction of purely verbal models as well. Economic networks of directly interdependent agents acting without any central control are ubiquitous in current times: The increasing fragmentation of valued added chains, the growing importance of network-based information and tele-communication technologies, and the ever more centralized industrial structure with few huge corporations and many smaller, globally dispersed, sub-contractors (and the resulting hub and spoke networks) make it essential to pay attention to the underlying network structure in the economic system under consideration. ABM can be an indispensable tool if one wishes to explain rather than just to describe the role of network structures: problems including network structures quickly become intractable in an analytical sense. Purely verbal models, on the other hand, are not accurate enough to capture important differences of various network structures, even in a qualitative way.

#### **4.3.4 Evolution and agency**

As an alternative to neoclassical equilibrium analysis, institutionalists developed concepts such as circular cumulative causation, path dependence and reconstitutive downward effects. Much appeal of ABM stems from the fact that they can constitute non-linear dynamical systems exhibiting such non-ergodic properties, based on intuitive (behavioral) assumptions (Edmonds, 1999; Arthur, 2006). For neoclassical models (in the wider sense) it usually requires quite a bit of axiomatic variation (Kapeller, 2011) to derive such properties within their optimization-cum-equilibrium framework.

Evolutionary economists have already recognized the usefulness of ABM when developing the concept of “History-friendly models” (Malerba, Nelson, Orsenigo, & Winter, 2001; Orsenigo, 2007). This concept tries to bridge the extremes of conducting very detailed and specific case studies, and to design abstract and general theories:<sup>10</sup> One starts with concrete case studies and then expresses the verbal arguments rigorously in a formal language. For such purposes, the

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<sup>10</sup>Note that these arguments are very similar to those of Radzicki (1988), who argued for the application of system dynamic models in OIE.

formalism has to be sufficiently flexible to include sufficiently realistic assumptions. ABMs meet this criterion. The parameters of the resulting model get calibrated according to empirical observations or on the basis of sound theoretical assumptions. Then the model is used to assess the empirical consistency, robustness and generality of the verbal arguments by comparing the resulting dynamics of the model to the true dynamics of the case study. If one is able to replicate past behaviour of the system by having identified the central causal mechanisms, one can change the model in order to construct alternative histories, e.g. to assess certain policy interventions.

History-friendly models are a nice example of a concept that has been developed largely in the evolutionary economics community, but is highly relevant for OIE thinkers, e.g. for the study of institutional change. Murmann and Homburg (2001) stress that rigorous case studies are a prerequisite to proceed to the formal (history-friendly) model. OIE scholars have already developed many of such historically grounded case studies and can build upon this work. For this task, ABMs have proven successful (Malerba et al., 2001).

But the evolutionary flavor of ABMs is not limited to the aggregated level: The agents themselves are not static and rational, but can be boundedly rational and adaptive. Their reasoning is not necessarily deductive, but, following psychological evidence, can be inductive and based on heuristics. They are not isolated representative entities, but socially embedded agents (Edmonds, 1999; Pyka & Fagiolo, 2007).

An adequate representation of the economic agents is not only an important tool to make models evolutionary in the institutionalist sense. It also contrasts the instrumentalist use of rational agents of neoclassical economics with a representation of the economic actor that involves an adequate level of descriptive accuracy. It helps to develop models that meet empirical findings on different ontological levels (Pyka & Fagiolo, 2007).

This aligns well with the research praxis of institutionalists not to stop with the postulation of a certain preference relation but to elaborate and justify their particular behavioral assumptions more concretely. More concrete motives include a thirst for power, altruism, an instinct of workmanship, idle curiosity, conspicuous consumption and time and space dependent habits (see Rengs and Wäckerle (2014) for a concrete example).

Again, there are strong convergences between OIE and modern evolutionary economics: Both seek a more realistic conception of economic agents and argue for assumptions justifiable by evolutionary theory, termed “the principle of evolutionary explanation” by Hodgson (2004, p. 157).

Developing an adequate conception of agency for ABMs consistent with this principle represents an alternative research trajectory than that of neoclassical economics: realism of its agents is less important and a common reaction to criticisms of the utility-maximising homo oeco-

nomicus has been the use of more and more complex utility functions (e.g. by including social preferences or by adding ‘decision defects’). Thus, it missed the essence of Herbert Simon’s idea of bounded rationality, according to which agents reduce the complexity of their decision process due to a lack of computational capacity. They employ heuristics to cope with the complexity of their environment, rely on institutions and make decisions more inductively than deductively.<sup>11</sup>

ABMs can follow this more promising research trajectory using institutional and evolutionary theory. Already the work of Herbert Simon highlighted how adequately human reasoning can be represented via algorithms.<sup>12</sup> More sophisticated decision procedures could be included using genetic algorithms. Genetic algorithms represent heuristics that help to solve optimization problems in a satisfactory way if a straightforward maximization is not feasible. It starts with a set of possible solutions to a problem, evaluates them according to a criterion, combines them randomly based on their performance and evaluates the resulting combinations again. By proceeding this way, the results usually become better and better. Such algorithms mimic the principles of natural selection and can explain not only many biological phenomena but also how certain instincts and behavioral habits have come into existence (Mitchell, 1999).

When employed on agents, they can help to simulate the learning behaviour of agents and their way of adapting to their environmental requirements. This is one source for the ability of ABMs to describe non-reversible dynamics and to resemble the principle of (circular) cumulative causation and the path dependence of real world dynamics.

#### **4.3.5 Newer trends in evolutionary and institutional economics**

In addition to the core principles of institutionalist methodology discussed above, it is necessary to have a closer look on actual methodological trends within institutionalism.

Important methodological conclusions emerged from the discussions about the potential application of (evolutionary) game theory and system dynamics in institutionalist research: In both cases, the formal models were motivated by the observation that traditional, mainly verbal, pattern modelling does not allow for sufficient logical depth and rigour to address complex situations with different mechanisms playing an important role (Radzicki, 1988; Heap & Varoufakis, 2004; M. C. Vilena & Vilena, 2004). These arguments apply in a similar manner for ABM: it allows to formalize different mechanisms very precisely without coming up with an analytical straitjacket limiting the descriptive richness of the resulting model.

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<sup>11</sup>Velupillai and Zambelli (2011) used the term “modern behavioural economics” to contrast the neoclassical approach to bounded rationality in contrast to the “classical” approach from Herbert Simon and Alan Turing, among others.

<sup>12</sup>In particular, the logical theorist, one of the machines built by Simon and Allen Newell, was the first machine that could prove mathematical theorems and solve logical puzzles on its own and in the same manner than humans do.

Another discourse is about a closer orientation of OIE on Darwinian core principles: Some argue that evolutionary economics necessarily have to be built upon the Darwinian principles of variation, selection and replication (e.g. Hodgson (2002) or Hodgson and Knudsen (2010)). Others claim that these principles are of great importance to understand and define the framework conditions of economic activity (such as humans cognitive capacities, instincts, etc.), but are ill-suited to study the resulting dynamics and cultural evolution within the actual economic sphere (e.g. Witt (2004) and Cordes (2006)).

None of the two positions is incompatible with ABM. To the contrary: both approaches emphasize the importance of a realistic conception of economic agents, their habits, heuristics and cognitive abilities. As illustrated earlier, ABMs can be useful in this context. The same can be said of out-of-equilibrium dynamics and self-organisation.

In the end, none of the actual methodological trends changes the classical cornerstones fundamentally and all of them are likely to profit from the application of ABM.

## 4.4 Discussion

### 4.4.1 Major chances...

While the proceeding section focused on how ABMs fit into the general criteria of institutionalist pattern modelling, I now make some more general statements about how ABMs can contribute to institutionalist research.

**Identification of causal mechanisms** ABMs help to identify whether a factor or mechanism is sufficient or necessary to produce a certain pattern. In sharp contrast to the *ceteris paribus* analysis in neoclassical economics, it studies the dynamic interaction effects of several factors or mechanisms (e.g. the role of networks as a catalysator for other factors as discussed in Section 3.3). Such interaction effects are difficult to identify in purely verbal models. Furthermore, ABMs can help to study how in an open system different initial states and trajectories can lead to the same long term behaviour. For open systems, this property is known as equifinality. It is important to identify equifinality because in order to explain an observed phenomenon, it might be insufficient to provide one universal explanation. In open systems, the same phenomenon can be reached via very different ways and from very different initial conditions. It is therefore important to provide a constructive explanation of a phenomenon, i.e. to show the exact mechanism that leads to the presence of the phenomenon of interest, and what other factors can yield the same result. Such a constructive explanation is naturally implemented in ABMs.

**Generalization of case study results** Case studies are much more common in the institutionalist literature than in conventional economics. This may partly be because facing the trade-off

between accuracy and generality, mainstream economists tend to favour the latter in order to allow a wide area of applicability (Gilboa, Postlewaite, Samuelson, & Schmeidler, 2014) while institutionalists favour accuracy above generality.

There are some exceptional, more general theories developed by great institutional minds such as Gunnar Myrdal (circular cumulative causation), Clarence Ayres (the nature of technology and skills), and Thorstein Veblen (e.g. conspicuous consumption, institutional life cycle). Although Diesing (1971) considers these concepts to be a mere grouping of real cases, I prefer to see them as mechanisms taking place in different real world situations.

Following the example of history-friendly models, we saw how ABM can help to proceed from the appreciative learning from cases to a formal model illustrating a general mechanism (cf. Nelson and Winter (1982)).

In this way, ABMs represent a more rigorous way than the vague concept of contextual validation of Wilber and Harrison (1978). Due to their accessibility to a wide range of verification techniques on different scales (microcalibration, macrocalibration,...), ABM can help to compare institutionalist models much more concisely with observed data than a verbal analysis, but more transparently and appropriately than a purely econometric analysis.

**Consideration of scaling effects** Not all properties of a system are emergent. Some are only an aggregation of the individual components. An interesting question is therefore to what size a system, e.g. the society, can be reduced (or ‘scaled’) without losing its emergent properties. Emergent properties that are the result of interactions among the components might require a certain minimum group size of components that interact directly and indirectly with each other. To understand this minimum group size means to study the degree of scale invariance of the properties. It can conveniently be carried out via ABMs by controlling for the number of the agents considered. Such a study is relevant for many applied institutionalist concepts such as the varieties of capitalism research program and the evolution of cooperation in communities.

**Increased transparency** Recent incidents such as the misleading study of Reinhart and Rogoff (2010) were grist to the mills of all critics of formal modelling in general. But such criticism goes too far. Formalization, if done and assessed carefully, can improve the transparency of theories significantly compared to purely verbal descriptions:

ABMs, as a particular kind of formalization, combines the advantages of verbal descriptions, i.e. the flexibility to choose assumptions based on empirical or theoretical convincing arguments, rather than tractability considerations, and analytical models, i.e their precision and rigour. ABM can be considered the ‘golden middle’ between these two extremes.

As such they allow an extremely rigorous test of the validity of the formalized arguments: Every assumption needs to be represented via the computer code. In the ideal case, the code gets published after the publication of the model: everybody could check how the results depend

on the assumptions and the replication of the study gets simplified. Such ‘open source’ ABMs guarantee a maximum level of transparency about how the researcher comes from his assumptions to the conclusions, as the very process of deduction becomes itself subject for public assessment. Many authors already distribute their code on request which makes it easy to use their models for educational means, e.g. in graduate training.

**Better policy advice** Building upon all the aforementioned points, ABMs are predestined to elaborate reasonable policy advice. This usefulness is one of the main arguments in favour of their application within institutionalism.

They may not only provide analogies, but provide concrete results which are subject to replicability and critical scrutiny by all parties involved. Also, due to the fact that the state of each agent is not necessarily expressed in only one dimension, ABMs are able to provide a multidimensional perspective considering inconvertible properties such as ‘literacy’ and ‘income’. This has been advocated by institutionalists ever since (Myrdal, 1978) and helps to avoid abstract concepts such as ‘utility’, which can become misleading when elaborating policy advice.

In this context, history-friendly models provide a nice example of potential collaboration among evolutionary and institutionalist economists. Their ‘alternative histories’ produced by history-friendly models represent an optimal base for a discourse on adequate policy responses. And while the existing models focus very much on the evolution of industries and technologies, institutions have so far been a less active area of research.

Another important advantage in this context is the constructive character of ABMs: In a dynamic economy, it is important to take adjustment paths into account. And while many analytical models are not capable of describing the exact adjustment paths (e.g. game theoretic models hinting to an existing Nash equilibrium), ABMs truly generate their results step by step in a transparent manner (Epstein & Axtell, 1996).

#### 4.4.2 ...and major challenges

The application of ABMs is, of course, not without difficulties. These are in particular the following:

**Instrumental tendencies** ABMs tempt researchers to take a constructionist-instrumental standpoint that seems to be incompatible with institutionalist epistemology and ontology. Instrumentalists do not try to describe the reality accurately but consider their theories to be mere instruments replicating observed data.

As institutionalists have been skeptical to the idea that economic outcomes can be predictable at all, their focus has always been on building explanatory models. ABMs are, of course, simplified abstractions of real world economies. But strictly speaking they share this property

with any model, including verbal models.

But as ABMs do not necessarily include the dominant equilibrium condition, they can include different mechanisms, others than the aggregation of the behavior of utility-maximising agents. This allows a mechanism-based rather than a prediction-oriented study of the overall system.<sup>13</sup>

**Implicit focus on predictive power** Related to the preceding difficulty, ABMs are frequently used to predict economic outcomes. In this sense, they are perfectly compatible with Friedmans methodological instrumentalism. If one tries to explain an economic phenomenon of a certain time period via the use of an ABM, one might be tempted to proceed a few time periods more in order to predict the further development of the system. One might then tune the model in a way that the predictions fit one's theoretical convictions and in turn accept a lower level of explanatory accuracy. Such an approach is difficult to be identified later on and requires an intensive review of the ABM.

**Overerparametrization and decreased transparency** ABMs tend to be overparametrized. Overparametrization means adding variables, processes and methods until one gets a very good fit to data or is able to create the patterns one wishes to explain. Overparametrization yields extremely complicated models that are very hard to review and hard to discuss. Good ABMs can help to identify important factors and to increase the transparency of a study, bad ABMs do the reverse. The problem of overparametrization of ABMs is well known and there has been an enormous progress in developing methods to test for overparametrization.

Such tests are difficult and cumbersome, however. They require excellent knowledge of the relevant literature. Newcomers must often rely on the judgements of others. But one must recognize that other quantitative models and verbal models are also vulnerable to overparametrization. It is therefore important to have this problem in mind, but not to throw the baby out with the bath water. One must never forget that the contrary, 'underparametrization', can be misleading as well.

#### **4.4.3 ABMs are compatible with the Institutional approach**

Based on the above said one can conclude that ABMs may be affine to institutionalist pattern modelling. There are some qualifications to this conclusion, however.

ABMs are abstract mathematical models and must be embedded into a more general process story to get explanatory significance. This process story should be consistent with the criteria for institutionalist storytelling and provide strong theoretical underpinnings for the ABM. Especially, the assumptions must be justified and the range of applicability of the models be clarified. It

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<sup>13</sup>This has been particularly the case since the dominance of the programming paradigm called object oriented programming (OOP). The idea behind OOP is to build programs by defining objects corresponding to some entity in the real world, and methods on these objects corresponding to processes in the real world.

is crucially important that it is always the theory that dictates the choice of the formalism, not vice versa. The overall insights of a study can never be reduced to the model outcome - only the interpretation of the results in the broader and therefore necessarily verbal discussion yield scientific progress.

After having considered the case of OIE, some concluding thoughts about ABM in institutional economics in general might be in order: Many of the arguments made above also apply to new institutionalism: Especially the Austrian wing of new institutionalism may profit from the application of ABMs. Leading scholars such as Hayek have always accentuated the self-organizing nature of the economy and the important role of human agency. Self-organization and a rich agency can, as has been made clear, be successfully studied in the ABM framework.

## 4.5 Conclusion

I have argued that ABMs can be a valuable heuristic and analytical tool for institutionalist research. They are useful for building holistic, systemic and evolutionary models in the sense of Wilber and Harrison (1978) and Myrdal (1978). This paper also contributed to institutionalist methodology in a more general way by showing that it is modern systemism that best describes the institutionalist perspective on the economy. Wilber and Harrison (1978) would have chosen this term to describe institutionalist pattern models if they had written their article today.

All considered, this article suggests institutionalists to be open-minded to the application of ABMs as they entail a large potential to clarify important and so far unresolved questions. This is particular true for phenomena related to networks, aggregation (and scaling) behaviour and the development of policy measures. They entail the desirable rigor of a more formal analysis, but avoid the compulsory formalism of neoclassical economics: They could be seen as the golden middle between a purely verbal and a formalistic approach to modelling. As even the process of building a model may already help to get new insights into the subject, they can also be considered to be a topos, i.e. a concept making the researcher ask important questions about the subject of investigation.

Unfortunately, to get started with ABMs is not a trivial task. ABM projects are usually realized by a group of researchers, including people with good programming skills. Yet it is important to learn about the basics of building ABMs, even if you collaborate with other scientists who support you in the implementation. The following resources will be helpful to get a better intuition for ABM: Leight Tesfatsion's website provides an excellent overview over existing resources, including tutorials and online courses. Axelrod and Tesfatsion (2006) is meant as a guide for newcomers to ABM and the handbook of Edmonds and Edmonds and Meyer (2013) includes many useful contributions for beginners. Finally, the Complexity Explorer project from



the Santa Fe institute offers an online course on ABM in Netlogo.

This paper suggests several lines for further research: In particular, neo-Schumpeterian and OIE scholars should consider joint projects under the methodological umbrella of ABM: This will be particularly fruitful for policy-relevant cases, where institutional and technological change are both important. Many synergies are to be exploited. Several institutionalist applications of ABM, such as Hodgson and Knudsen (2004), Elsner and Heinrich (2009), Heinrich and Dai (2014) and Rengs and Wäckerle (2014) could serve as vantage points for such research.

Further research may also address how the application of ABMs relates to critical realism, which has been becoming a more popular philosophical basis for institutionalist modelling. It tends to be even more sceptical of any kind of formalization.

Such an investigation might further clarify the relation between critical realism and institutionalism and may further strengthen the methodological base of institutionalist modelling.

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# Chapter 5

## Formal Approaches to Socio Economic Analysis - Past and Perspectives

### Chapter Abstract

This chapter is motivated by the observation that (1) socio economic analysis uses significantly less formalisms than mainstream economics, and (2) that there exist numerous situations in which socio economics could benefit from a more formal analysis. This is particularly the case when institutions play an important role in the system to be investigated.

Starting with a broad conception of a formalism, this paper introduces and discusses five different formal approaches regarding their adequateness for socio economic analysis: The Social Fabric Matrix Approach, the Institutional Analysis and Development Framework, System Dynamics, (Evolutionary) Game Theory, and Agent Based Computational Modeling.

Every formalism entails implicit ontological and epistemological tendencies that have to be reflected on if the formalism should contribute to a better understanding of the system under investigation. The above mentioned formalisms are no exception. Therefore, this paper pays particular attention to these tendencies.

In the end, antagonisms and possible convergences among the formalisms are discussed.

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## 5.1 Introduction

“The tool kit is not as important as the perspective, but it is imperative for giving the perspective meaning in any applied sense.”

Hayden (1982, p. 638)

To conduct a socio-economic analysis means to seek understanding of the relationship between the economy and society. The role of social and economic institutions plays a key role in any such attempt and a natural overlap between the schools of social and institutional economics exists.

This is particularly true for the part of institutional economics termed *original* institutional economics (OIE). The other part, the new institutional economics (NIE), puts scarcity and competition at a central stage of analysis, considers markets as a superior way to allocate scarce resources in a society (Ménard & Shirley, 2014, Special Issue 04, p. 557) and shares the conviction that institutions must be explained with (at best boundedly) rational individuals as the starting point. Only limited attention is given to the question of how their preferences come about (Hodgson, 2004, p. 6). Despite this limited scope, new institutionalists have produced many more formal models than socio economists or original institutionalists.

This paper was motivated by the observation that while formal analysis plays a more prominent role in NIE, it is used quite sparsely in the overlapping work of OIE and socio economics. Why is this the case and could a more extensive use of formalisms increase the productivity of social economics as a discipline? Are social economists and original institutionalists against formal arguments *per se*?

A closer inspection shows that at least the latter supposition is wrong. The rejection of many common mainstream formalisms is based on specific and reasonable arguments, e.g the critique of the orthodox *optimization-cum-equilibrium* approach for requiring an excessive and specific reduction of complexity to keep its models tractable. Also, Galbraith (1967), among others, convincingly argued that powerful economic actors make their strategic choices not mainly as a reaction to their environment, but mainly in order to change this environment. Galbraith uses the example of big business corporations to illustrate this point. This form of different motivations and a mutual interdependency of choices and the agent’s environment is rarely captured in a formal analysis.

Similarly, a socio economic analysis requires the consideration of values, traditions, habits and the different motives governing the behaviour of economic agents. To consider these aspects adequately in a formalism similar to that of orthodox neoclassical economics (that includes many *implicit* value judgements itself) is impossible.

Another source for the scepticism against formal models stems from Veblen (2011[1908]). For Veblen, mathematics “in its pure form” is a logical discipline only. Its results are only

assessed regarding their logical consistency or elegance and it deals with logic, rather than the “ephemeral traits acquired by habituation” (Veblen, 2011[1908], p. 489). It is therefore “independent of the detail-discipline of daily life” and “independent of cultural circumstances”.

This statement aligns well with Veblen’s claim that modern, i.e. evolutionary, sciences can by definition only get to transitional results, as their fundamental postulate is that of continuous change in the real world. And if there is continuous change, all results are time (and probably space) dependent and thus provisional. This perspective is shared by many socio-economists, but is incompatible with the equilibrium approach that underlies the majority of economic models today (Jo, 2011). These models are criticized for neglecting the the cumulative change that has led to the current state of affairs and are not considered to provide valuable insights as they can only be seen as small snapshots within greater societal dynamics. A related critique argues that mathematical models too often create a model world that does not represent anything in the real world, neither whose mechanisms resemble the mechanisms of the real world.

This criticism certainly applies to some mathematical models, but there is no a priori reason to believe that it applies to all. Mäki (2009) developed a framework, the functional decomposition approach to modeling, that, from a realist perspective, helps to scrutinize the extent a model represents the real world. This clearly shows that not all mathematical models constitute what Mäki calls *substitute systems*, i.e. artificial systems that are studied *in place of* the real world, rather than *in order to understand* the real world.<sup>1</sup>

All the formalisms considered in this paper do not fall into the latter category. Neither are they “mathematics in its pure form”. They include or require a theoretical framework into which they are embedded and which guides their interpretation: A mathematical function in a model is nothing more than a function. The theory motivating the models helps to interpret this function with respect to the real world. These interpretations have to be rigorous and transparent. If they are not, the criticism of Veblen will apply and the model gets separated from daily life and its institutions (Veblen, 2011[1908], p. 490). But the examples discussed in this paper hint at how one can circumvent these problems through an adequate theoretical framework, as will be illustrated during the exposition of the different formalisms.

This paper discusses some formalisms that I consider to be particularly attractive candidates for socio economic analysis. Each of them has particular advantages that can enhance socio economic analysis in a particular sense, be it, e.g., an increase of the logical depth of the argument (game theory, system dynamics), the possibility to study phenomena that cannot be subject to verbal analysis (agent based models) or by structuring the overall assessment (SFM and IAD). All of them have to be treated with some care as formalisms always shape the analysis in a certain, often not obvious way. Consequently, I will pay particular attention to the implicit

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<sup>1</sup>I have extended this framework and illustrated its usefulness for the examples of agent-based models and dynamic stochastic general equilibrium models in Gräbner (2015b).



epistemological and ontological tendencies of the formalisms.

At this point it seems to be adequate to define what I mean when using the term ‘formalism’. In a very narrow sense, a formalism denotes any abstract language, such as mathematical or logical formulas, or a computer language. We may call these *formalisms in the narrow sense*. But to limit the term to systems of such expressions seems to be too restrictive for our purpose: A table that is to be completed via verbal words and then carries a specific message can also be considered a formalism: Its structure carries information and shapes the meaning of the words that have been used to complete it.<sup>2</sup> The working definition we will use for such a *formalism in the broader sense* defines it as a set of abstract or specific objects that are related to each other in a certain way and which can be specified further in the course of analysis. Such a definition captures the central idea of a formalism: A *pre*-defined set of variables and a *pre*-defined set of relations that are then put together and specified by the modeller who makes use of this formalism. The notion of *pre-specification* is key: It carries meaning that has to be reflected on if the formalism is to be used successfully.

The rest of the paper is structured as follows: In the next section I present four formalisms that have already been used successfully in institutionalist theory and that I consider to have particular potential for socio-economic analysis.<sup>3</sup> In section 5.3 I propose agent-based models as another useful formalism in this sense. As it is not yet well established in current research praxis, I spend some more space on explaining its affinity to social economics. Section 5.4, after introducing a useful taxonomy for the formalisms, discusses their ontological and epistemological tendencies and elaborates on potential complementarities and antagonisms among them. Section 5.5 concludes.

## 5.2 Established Formal Approaches

### 5.2.1 The Social Fabric Matrix

The Social Fabric Matrix Approach (SFM-A) was developed by Hayden (1982) and summarized recently in Hayden (2006a). Since its invention it has been used by institutionalists many times and represents one formalism consistent with OIE methodology. See Fullwiler, Elsner, and Natarajan (2009) for a detailed assesment of this claim and a number of case studies illustrating the substantial usefulness of the approach. As such it seems to be a natural candidate to study institutions within a broader social economic analysis. A SFM is a map that includes all the

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<sup>2</sup>The social fabric matrix and the institutional analysis and development framework are examples of formalisms in this broader sense.

<sup>3</sup>Note that there are other formalisms that have been successfully applied by socio-economists. Yet, it is impossible to consider all of them in this single paper. The selection was made in accordance with my impression about the overall relevance of the formalisms, the degree of controversy associated with their application and with my personal preference. For an overview on other candidates see Radzicki (2003), F. Lee and Cronin (forthcoming 2015) or the special issue of the *American Journal of Economics & Sociology* (F. S. Lee, 2011).

relevant components of the system under investigation and represents the relations and flows between these components.

When written in matrix form, the rows and columns represent the different components of the system that the researcher has identified. See figure 5.1a for an example. The rows contain all the delivering components, the columns, the receiving components and the values in the cells denote either the existence or absence of a direct relation among the components (if only boolean values are allowed) or the strength of the relationship (if the value is some measure for the existent flow). Note, however, that the SFM is a multidimensional tool, i.e. the relations and flows of the SFM are not necessarily measured by the same unit - this distinguishes it from simple Input-Output matrices.

Thus the matrix gives an overview of all the relevant flows in the system under investigation. But, for many researchers an even more important point, the process of completing the matrix helps one to ask new and relevant questions on the subject matter and to discover components and relationships that would have stayed unconsidered otherwise (Fullwiler et al., 2009, p. 12). The SFM can therefore be considered a heuristic forcing the researcher to think about the whole system in which the concrete problem is embedded into and to identify the relevant variables and relationships of this system. Because there are no pre-completed SFM, the researcher has to build her matrix anew from scratch, which forces her to justify her selection of relevant factors explicitly. The flexibility of the matrix prevents unreflected reference to standards, a common mistake in the application of many formalisms. To the contrary, the matrix stimulates researchers to be explicit about their subjective valuations.

As the matrix can naturally be interpreted as the adjacency matrix of a graph, the matrix shown in figure 5.1a could also be represented in graph form, see figure 5.1b. If the matrix was completed using boolean values denoting the existence or the absence of a relation between two components, the result would be a simple digraph. If the values in the cells were a measure for the degree of relation, a weighted digraph would result - although the different weights are not necessarily comparable.

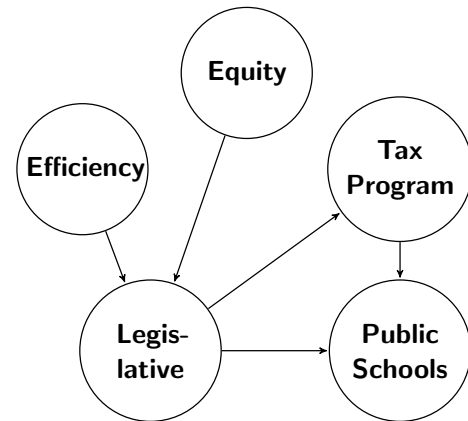
The interpretation of the SFM as an adjacency matrix yields many advantages. In particular, one can use numerous useful graph theoretic concepts to deepen one's understanding of the system under investigation: For the resulting graph, reachability problems can be studied: In the logic of a graph, a reachability problem asks for the existence of a path from node  $v_1$  to node  $v_2$ . In the context of the SFM this asks how different components are indirectly interrelated, and, if the graph specification includes weights, how intense the interrelatedness is. One can also compute the degree distribution or other measures of centrality in order to assess the relative influence of the different components.

The SFM-A is probably the most widely used integrated framework within OIE. It has been developed particularly for institutionalist analysis, and numerous scholars have used it in their analysis.<sup>4</sup> Users stress that the matrix helps to structure research, suggests ever new

<sup>4</sup>For a corresponding compilation see Hayden (2006a), or consider Tool (2003) and Fullwiler et al. (2009) for a

		Receiving				
		Equity	Efficiency	Legislative	Tax Program	Public Schools
Delivering	Equity			1		
	Efficiency			1		
	Legislative				1	1
	Tax Program					1
	Public Schools					

(a) An example for a SFM.



(b) The SFM represented as a directed graph.

Figure 5.1: An example of an SFM (subset of the original matrix) and a corresponding graph, based on Hoffman and Hayden (2007).

interesting questions and forces the researcher to take a systemic perspective on the system under investigation (Fullwiler et al., 2009). Furthermore, it does not require any inappropriate reduction of complexity or abstraction from dynamics and is flexible enough to consider many different aspects of the system, reaching from environmental variables over institutions and organizations to the value system and persistent behavioral patterns. Especially when interpreted as a directed graph, it has helped to generate surprising and policy relevant results, e.g. by considering the contractual structure associated with the construction of a nuclear dump side by the Central Low-Level Radioactive Waste Compact in Nebraska, USA, in collaboration with several big companies. Hayden and Bolduc (2000) were able to reveal the corresponding costs for the public that are, due to the contractual structure and the resulting system of positive feedback loops, much higher than one initially would have expected. As a consequence of these results, the project was abandoned.

## 5.2.2 Institutional Analysis and Development Framework

The IAD is a general framework for the study of institutions and their development over time. It was developed mainly by Ostrom (1990)<sup>5</sup> and has been applied in many different occasions. For Ostrom, frameworks are meant to illustrate the elements and relationship required for the analysis at a most general level and thus to structure the following inquiry (Ostrom, 2011, p. 8). The IAD is structured as illustrated in figure 5.2.

At the center stage of the framework is the *action situation*. This is the arena in which the actors (inter)act and from which the dynamics of the system are triggered. The identification of the action situation is one of the first steps the researcher has to take after the problem at hand

summary of the impact the SFM-A had on public policy.

<sup>5</sup>A more thorough introduction can be found in Ostrom (2005).

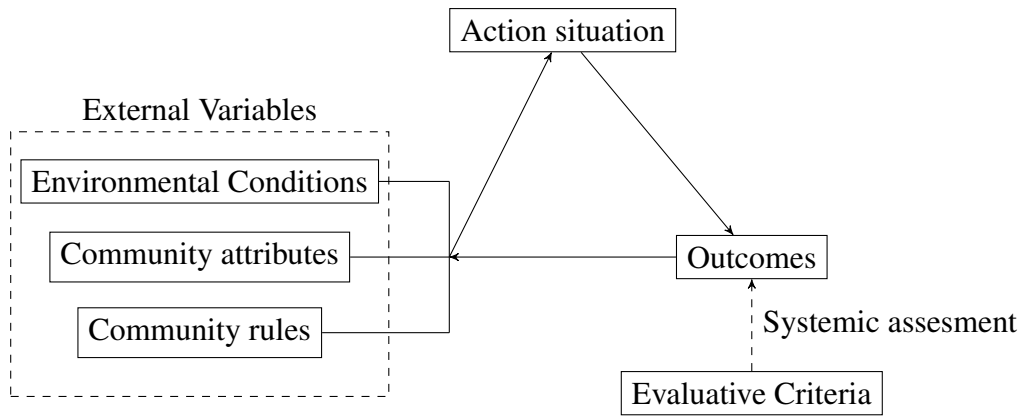


Figure 5.2: An illustration of the IAD, following Ostrom (2005, p. 15).

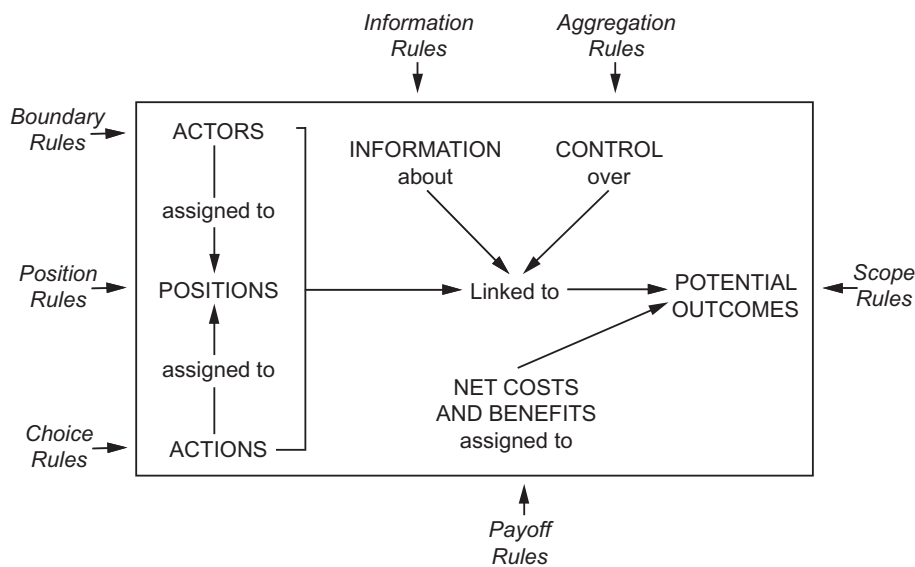


Figure 5.3: A closer illustration of the action situation, taken from Ostrom (2011, p. 20).

has been defined. As illustrated in figure 5.2, the action situation is embedded into a broader analysis:

The environmental conditions, the attributes<sup>6</sup> of the community and its rules all have significant influence on the action and interaction of the individuals. Sometimes the outcomes from the action situation influence the environmental conditions which then in turn act upon the action situation. The emerging feedback loops can be identified and clarified using the IAD. In the very simplest case, however, one assumes the external variables to be constant and focuses one’s analysis on the action situation alone. Figure 5.3 illustrates how the analysis of the action situation proceeds. Usually one develops a particular model to study the action situation in more detail. For Ostrom, several models can be derived from the same theory, and different theories are compatible with the IAD. It is therefore entirely possible to model the action situation using

<sup>6</sup>Attributes of a community include, but are not limited to, the level of trust and reciprocity, habits, the value structure or cultural dispositions.

purely neoclassical models, game theoretic models or any other kind of model (e.g. agent based models, see section 5.3).

If one treats the variables marked as ‘external’ in figure 5.2 as exogenous variables, one is concerned only with a model including the seven aspects illustrated in figure 5.3: The set of actors containing all individuals involved, the set of positions the individuals can occupy (e.g. managers, employees, members of an association, etc.), the set of actions that the individuals can take, the description of the control individuals have on their choices (i.e. are decisions made in isolation, or do individuals act on the behalf of others?) and the information available to the individuals, the set of potential outcomes of the aggregated individual actions and a description of how these outcomes represent costs or benefits to the individuals. All relevant information has to be gathered before the actual modeling process can begin. Then one makes assumptions about the behaviour of the individuals, their wishes, beliefs, their capacities, and so on. Although the most widely used approach would be to use the conventional neoclassical utility maximizer as a starting point, this is by no means required by the IAD. To the contrary, the questions suggested by the IAD point to a more realistic and socially embedded actor. The experiments of Ostrom, Walker, and Gardner (1992) on the mechanisms underlying sustainable self-organization of common goods within communities were motivated by the observation that, if one tries to understand how communities manage their common goods without running into the problems of the ‘Tragedy of the Commons’, the conventional game theoretic individual will not be an adequate candidate for the individuals in the action arena. Therefore, Ostrom refined her model of individuals *within* the broader IAD framework.

In many situations, it does not seem to be adequate to consider the action situation in isolation and to assume the external variables to be exogenous. For a systemic scrutiny of the problem at hand, as it is required in institutionalist pattern models (Wilber & Harrison, 1978; Gräbner, 2015a), one models the external variables endogenously. Ostrom (2011) suggests a taxonomy according to which one can incorporate the rules of the community under investigation into the action situation, as illustrated in figure 5.3. Such a refinement is entirely possible in and suggested by the IAD which could in general be interpreted as a sophisticated *topos* guiding the researcher’s thinking, rather than a full-fledged modeling tool.

Another crucial part of the IAD is the very right part of figure 5.2: The evaluation of the dynamics resulting from the action arena. The evaluation criteria must be specified by the researcher in advance and depending on her theoretical orientation they can include only aggregate and monetary measures, or can be multidimensional, as required for a social economic analysis.

Summarizing the above: The IAD framework is an extremely general framework that is compatible with many different theoretical directions. It has gained an enormous popularity among scientists and practitioners and is now used in various scientific communities, see Ostrom

(2005) or Hodgson (2013a, 04) for compilations of work consistent with a socio-economic viewpoint. These examples show that the value position of the researchers can be made very explicit due to the prominent role attached to evaluative criteria and that cultural habits, beliefs etc. can be included into the analysis of the action situation, allowing a truly systemic perspective on the problem at hand. It is to be noted, though, that the perspective of the IAD is much more focused on individual action than the SFM-A: The action situation is at the center stage, and the overall dynamics are derived from the arena, even if a continuous feedback between action situation, resulting outcomes and the subsystems of the entire system is possible. This issue will be discussed in more detail in section 5.4.

### 5.2.3 System Dynamics

System dynamics was originally developed by Forrester (1971) and introduced into institutionalist economics by Radzicki (1988), who argued that institutionalist pattern modeling (Wilber & Harrison, 1978) lacks structure, rigor and precision.<sup>7</sup> He hoped to address these shortcomings through the application of system dynamics, i.e. the computerization of the original pattern models (Radzicki, 1988, p. 636). For him, the computational modeling technique of system dynamics represents a computational approach not only broadly consistent with traditional institutionalist pattern modeling. He even goes so far as to state that “the only real difference between the two [system dynamics and institutionalist pattern modeling] is that the building of formal computer models is generally not a part of institutional analysis” (Radzicki, 1988, p. 634). He calls system dynamics and institutionalism two “parallel universes” (Radzicki, 1988, p. 639). Given the aforementioned overlap between institutional and social economics, it is also a natural candidate formalism for social economists.

A system dynamics model is a set of differential equations that is solved numerically. Its vantage point is the claim that individuals in a given system follow goal seeking behaviour (Radzicki, 1988, p. 640) and that the structure of a system, into which these individuals are embedded, is an important driving force of its dynamics (Radzicki, 2009, p. 70). The structure of the system involves its physical structure, organizational structure and the psychological decision making structure. Such an analysis is to be considered a systemic approach as the goal seeking behaviour of the individuals both affects and is influenced by the structure of the system.

The first step when building a system dynamics model is to identify the important variables (or ‘stocks’) of the system under consideration and the dependency structure among the variables (the ‘flows’). When considering the stocks, one must also pay attention to limiting factors, as most stocks (but not all) face some natural constraint: The number of workers is bounded by the overall population and the area of land is constrained by the size of the region. Such eventual limitations must be specified in the model. The stocks of a system are related to each other via

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<sup>7</sup>A thorough introduction can be found in Sterman (2000).

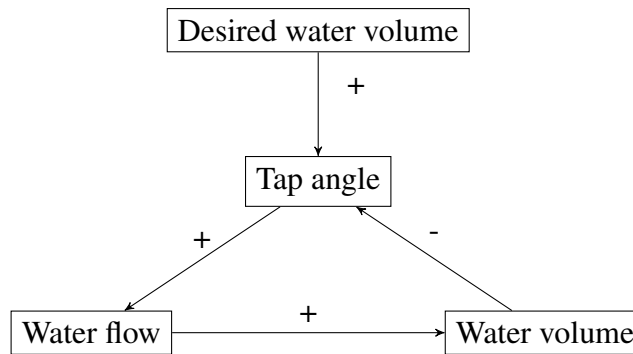


Figure 5.4: A simple causal loop diagram for a system dynamics model of a bathtub filling situation according to Lane (2008). This diagram assumes that if the water volume rises, one increasingly closes the tap in order to avoid flooding. Note that this is just a simplified illustration of the model and that the strength and direction on the relationships can vary, depending of the overall state of the model.

the flows, and the combination of these relations leads to the notion of feedback loops.

In the model building phase or when the model is presented to an audience, one can make use of *causal loop diagramming* in order to illustrate the feedback loops and causal relationship within the model: Stocks, flows and auxiliary variables are drawn as nodes of a directed graph, and the edges between two nodes represent a causal relationship between the stock and flow. The edges are labeled with either a ‘+’ or a ‘−’ depending on whether the relationship is positive or negative. See figure 5.4 as a simple example.

These loops are then expressed in differential equations that specify the relationships more precisely. Thus the system as a whole becomes a system of (usually highly non-linear) equations that is solved via numerical simulation. The most general formulation of a system dynamics model, given  $X = \{X_1, X_2, \dots, X_n\}$  as a vector of the stocks, and  $p$  as a vector containing all constants and the initial conditions, is therefore:

$$\frac{dX_i}{dt} = f_i(X, p), i \in \{1, 2, \dots, n\}. \quad (5.2.1)$$

Because of the use of differential equations, the system is inherently dynamic and the strength of the feedback loops can vary during the evolution of the model. And as an unambiguous analytic solution is not attempted, there are no general equilibrium assumptions made. For simplicity reasons, a model is often initiated in the equilibrium state. But this is an assumption made for convenience, not for technical necessity (Radzicki, 2010).

The translation of the theoretical model into equations and computer code ensures full transparency and maximum rigor in the model formulation. Note that the researcher continuously improves her knowledge about the system through the modeling process itself, as the obligation to state all relationships explicitly and precisely leads to ever new questions about the system under investigation. Similar to what has been said about the SFM-A, many authors (including the inventor of system dynamics J. Forrester) claim that the building of a system dynamics





### 5.2.4 Institutional Dynamics and Evolutionary Game Theory

Game theory has a long tradition in many different disciplines of science. It was introduced into economics by the mathematician John von Neumann and the economist Oskar Morgenstein in 1944. Since then, its importance, also, but not only, in neoclassical economics, has been growing dramatically.<sup>9</sup>

While original game theory is mostly in the tradition of the rational choice paradigm, biologists developed a derivation called *evolutionary* game theory that does not rely on the classical rationality axioms. It analyses how different strategies perform in different environments, under which circumstances they replicate and how they evolve over time.<sup>10</sup>

Several authors point to the potential of (E)GT for socio-economic and institutional economics. These include Field (1994), and more recently Hedoin (2010), Pelligra (2011) and M. C. Vilena and Vilena (2004). But there is also a lot of criticism of the application of game theory for a socio-economic analysis of institutions.

I argue that critiques of (E)GT often conflate the exclusive with the heuristic use of game theoretic models: Varoufakis (2008), for example, highlights the usefulness of a very stylized evolutionary game theoretic model to explain how discriminatory institutions emerge and cannot be changed by single individuals alone, but only through a process of collective action. Yet he concludes his paper with a critique of EGT for being agnostic on how such change may work, or on how to criticize the resulting system of exploitation. He, in turn, argues for a historical enquiry of the system under investigation to shed light on these questions. Valid as his remarks on the limitations of EGT may be, one should note that much of his reasoning builds heuristically on game theoretic models and that he makes extensive use of the taxonomy of interactions provided by game theory. When I argue that game theoretic models can be useful for socio-economists I do not say that they should substitute a historical account of the system under investigation or they are able to speak for themselves. Varoufakis (2008) is correct in rejecting such an isolated application of game theory if one wishes to understand societal systems. As all the other formalisms, game theoretic models require a sound theoretical framework that allows a sound interpretation of their mathematical structure and helps to elaborate on the consequences of the model outcomes beyond the scope of the mathematical apparatus. To clarify what this means, I will discuss a best-practice example: Paul D. Bush's *Theory of Institutional Change* and its refinement in a game theoretic framework by Elsner (2012) illustrates how socio-economists can and have made use of game theory to gain additional insights into the emergence and evolution of important institutions.

In his *Theory of Institutional Change* Bush (1987) established a coherent theoretical device to analyse the value basis for behavioural patterns and the resulting dynamics in the form of

<sup>9</sup>For a very good introduction into game theory and evolutionary game theory from an institutionalist perspective see Elsner, Heinrich, and Schwaradt (2014).

<sup>10</sup>Strategies are often interpreted as genes, but also as values, behaviour, habits or the like. There exist settings in which the strategies themselves are under ongoing change and players develop new strategies, according to the rules of Darwinian evolution, see e.g. Lindgren (1992).

progressive and regressive institutional change. Starting from the conception of an institution as patterns of behaviours correlated by socially prescribed values, he builds on the dichotomy of instrumental and ceremonial value systems and develops the distinction between ceremonially and instrumentally warranted patterns (Bush, 1987, p. 1082). Using the idea of ceremonial dominance, he argues convincingly how new technologies introducing new opportunities for instrumental behaviour generally do not lead to institutional progress as the new instrumental behavioural options get encapsulated through ceremonial values with more ceremonial or dialectical behavioural patterns. Progressive institutional progress is possible only if the ceremonial dominance in the society gets reduced by substituting ceremonial values with instrumental ones.

Enlightening as it is, the theory does not explain how ceremonial dominance *emerges endogenously* in a given society, which could, in principle, also be instrumentally dominated.

25 years later, Elsner (2012) took up the Theory of Institutional Change and addressed this shortcoming using an *evolutionary-institutional interpretation of game theory* in the Axelrodian framework of the evolution of cooperation. Elsner elaborates further complementarities and equivalences between the two approaches and stresses the similar policy prescriptions derived from the two perspectives (Elsner, 2012, p. 38). He argues that although game theory cannot provide an epistemological basis comparable to that of institutionalism, it can, if embedded into a broader institutionalist process story, add rigour and logical depth into the institutionalist analysis, can allow for a clearer distinction between different types of social rules and institutions, and enhance the institutionalist analysis, e.g. by offering an explanation for the initial emergence of ceremonial dominance in the context of Bush's theory.

The model of Elsner shows that if the application of game theory is not considered a value in itself and authors manage to provide adequate process stories into which they embed their game theoretic analysis, the game theoretical part, in the end, takes the form of a heuristic adding analytic clarity to the analysis. By doing so it enlarges their reach to more complex problem structures, which could not have been understood without the support of such a clarifying heuristic.

## 5.3 Agent-Based-Computational Models

### 5.3.1 Introduction and Affinity to Social Economics

Agent based computational models (ABMs) are a relatively new trend in the social sciences, although they are already well established in many other research disciplines such as urban planning, ecology, demographics, epidemiology, or logistics.<sup>11</sup>

When building an ABM one starts by programming the fundamental entities of a system as

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<sup>11</sup>ABMs have been used in the social sciences since the 1990s, with Epstein and Axtell (1996) and their "Generative Social Science" as a major vantage point. But there were some predecessors in the 60s, particularly in the field of cellular automata theory.

software objects. These objects represent autonomous agents and are able to interact with each other and their software environment. The latter can be programmed either as a software object as well or takes the form of statistical aggregates. In the former case, one could program an object representing an agricultural landscape, that can be exploited by the agents. An example for the latter case would be an aggregated variable representing the overall wealth of the agents. This variable may influence the behaviour of the agents, e.g. if middle-class agents behave differently than low-class agents.

One then studies the systemic and dynamic consequences that result from this configuration by simulating the system and conducts artificial experiments by altering specific aspects and comparing the resulting dynamics. Although the agents usually represent individuals, this is not necessarily the case: depending on the system under investigation, the agents can represent households, groups, organizations, or states.

The interaction among the agents can be entirely random or can be due to the topological structure of the model: One can allocate the agents on a (possibly changing) graph that represents an empirical interaction structure, on a grid on which the agents can make moves, or any other topological structure. This allows to model the agents as socially embedded and interdependent individuals.

Even more importantly, ABMs allows the study of decentralized decision making: There is not necessarily an artificial central planning institution such as for example the Walrasian Auctioneer in most general equilibrium models. Rather, the dynamics of the system modelled are the result of the autonomous interactions of the different agents and illustrate the self-organization a given system is capable of.

As the agents themselves are usually programmed in a computer language, a very flexible specification is possible: The digital objects representing the agents can have several attributes, such as income, saving, health, or a certain disposition. The objects also have functions, according to which these attributes change, and behavioural functions that determine the actions of the agents in certain situations. All these functions can have diverse inputs: The current state of the agent, but also current state of other agents or of the system as a whole. As suggested above, this means that, maybe contrary to what the name suggests, ABMs are not necessarily individualistic models: The behavior of the agents can depend on entities on different ontological levels: An agent can make different decisions depending on the state of the whole system, or on the state of a certain group of agents. One can create a software objects that represent a social institutions and affect the behaviour of the agents. By this, one is able to distinguish very precisely between two different conceptions of institutions: If institutions are nothing more than correlated behaviour that emerges because individuals have a memory and react to each other depending on their experiences with similar situations in the past, there is no causal interaction among different ontological levels and no downward causation in the strict sense. But if an institution is represented by a proper object (which may change over time and whose effect may

change depending on the support it gets from the agents) that interacts with the agents, then one can speak of a direct interaction of two ontological levels and thus proper downward effects.<sup>12</sup>

Thus, ABMs allow a very precise study of institutions, rules and networks on a potential meso level of the system and their corresponding relation to the individual agents (Elsner & Heinrich, 2009; Elsner et al., 2014). Also, the agents do not necessarily follow the same stimulus-response pattern the whole time, but can be given the ability to adapt themselves to their environment, learn from past experience and develop new objectives and strategies.

The above said immediately leads to the question of whether one could design an ABM with highly sophisticated artificial intelligence agents that resemble the behaviour of humans and thus guarantees a maximum level of realism. The fact that there is no unanimous answer to this question indicates the enormous heterogeneity of different perspectives within the ABM community: Advocates of the so called KISS ('keep it simple, stupid!') paradigm argue that ABMs in general should be kept as simple as possible and one should focus on the rules that are of essential importance for the research question, otherwise the models would itself become too difficult to understand and it gets impossible to identify the critical mechanisms that yield to the overall dynamics. Proponents of the KIDS ('keep it descriptive, stupid!') paradigm criticize the tendency to reductionism inherent to the KISS approach and argue that agents should be built in line with empirical results from psychology, anthropology and other empirical sciences concerned with human decision making.<sup>13</sup> ABMs are compatible with both world views, and most models take their place in between the two ideal cases. For socio-economists it is important that ABMs allow a certain degree of realism that makes them compatible with different epistemological perspectives, including the realist approach most widely accepted in social economics.

The heterogeneity of existent ABMs has already been mentioned. They represent entirely different economic perspectives with very different underlying epistemologies and ontologies: Some ABMs are considered macro models that want to model an economy as a whole, others model only one particular market or one particular region. Some of the models try to be as realistic as possible, others remain very abstract and illustrate the effects of some mechanisms in isolation. Some ABMs are built for predictive purposes only, while others serve only explanatory reasons. There are ABMs that are built for one particular system, e.g. the model of Geanakoplos et al. (2012) for the housing market in Washington D.C., others are built as generic models that

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<sup>12</sup>Note that the program does not tell you on which ontological level the different software objects belong. This information must be given by the theory underlying the model.

<sup>13</sup>If one considers the economic agents to represent the micro level, ABMs are suited for *microcalibration*. This involves a direct test of the adequateness of the agent design. It is common to consult field experts to judge the behavioural assumptions or to exchange the agent with a real human being 'playing' the role of the agent in the model and then by comparing how the software and the real human being have behaved. Because the behavioral specification of the agents is done via computer code, there is no upper limit for the complexity of the rules other than accountability considerations. Chen (2012) describes various types of agents including very elaborated artificial intelligence agents.

try to illustrate more general properties of systems, e.g. properties that are shared by any housing market in the USA. Also, the mechanisms included into the models are very diverse: Many ABMs were built to study the role of interrelations between agents such as different underlying network structures, others focus on the effects of particular decision heuristics. All this leads to very different epistemologies and ontologies present in the ABM communities.<sup>14</sup> It is clear that only a small subset of all these ABMs are of interest for social economists, but in the future they will (hopefully) increasingly build adequate ABMs themselves.

This seems to be appropriate as ABM can effectively address certain difficulties that social economists face at the moment:

If one considers the economy from a systemic point of view, one has to take the interaction among different ontological levels seriously. This involves the consideration of both aggregation problems and the scrutiny of downward effects. Especially aggregation mechanisms often lead to counter-intuitive results or are difficult to be expressed verbally. Take as an example the role of social networks and self-organization for the functioning of exchange systems: Albin and Foley (1992) have shown that even if one accepts all the usual axioms of the highly stylized Arrow-Debreu economy and only removes the fictitious Walrasian auctioneer in favour of direct interaction among the agents, the market will develop towards an equilibrium, but inequality among the agents will increase. Also, the way the interaction among the agents is structured, i.e. whether their interaction structure is modeled as a ring, a star or another type of network, influences the dynamics. Today, there is a huge amount of empirical evidence about how interaction networks in particular settings look like. These networks can be described with numerous statistical measures, e.g. their degree distribution, their centrality, their clustering coefficient or their density, among others. These statistics can make a huge difference in practice, yet they are very difficult to be described with verbal language. ABMs can help to build a theory of how different network structures affect certain exchange regimes and allow the use of the extensive information we have about real world networks and how their shape affects the aggregation of the individual actions within them.

Furthermore, ABMs help to study the causal effects of different decision procedures such as habit or inertia: As the decision making algorithms can be changed during artificial experiments with the model, we can elaborate how different cognitive procedures affect the system under consideration. Hodgson and Knudsen (2004) have built an ABM that studies the emergence and evolution of a traffic convention. The decision making procedure of their agents involves habituation and they show that habit and habituation can help people to coordinate on a certain traffic convention. They are also able to show that the effect of habit is particularly important and that it has a bigger effect than pure inertia. Such reasoning would have been impossible

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<sup>14</sup>Unfortunately, most model applications do not reflect explicitly on their epistemological orientation, which makes it difficult to assess the models from a critical perspective.

without the heuristic use of their ABM because verbal language does not provide the necessary exactness and does not allow artificial experiments to reveal the causal relationships. And it is of certain importance for social economists who accentuate the importance to treat human agency in a realistic and adequate manner.<sup>15</sup> Note that this is one reason for the increasing use of ABMs in sociology (Manzo, 2010).

### **5.3.2 Empirical Work and Relation to Econometrics**

Another huge potential of ABM for socio economists lies in their potential combination with econometrics. Econometric studies abound in social economics, especially because socio economists claim to work on a sound empirical basis and to orient their theory strongly on reality.

But econometric models require quite strict assumptions about the relationship of the variables in the system under consideration and the formalization of the hypothesis to be tested by the researcher. Not only are these assumptions sometimes not met: if they are not, this fault also often remains unconsidered for a long time, because more sophisticated estimation techniques allowing the identification of the problem have not yet been developed. In the (still unresolved) debate about the empirical validity of the Kuznets curve there have been periods in which certain estimation techniques or data sets were used by the majority of the researchers, resulting in general support for the thesis, until later the same techniques and data sets were shown to be inadequate, new methods were applied and the support turned into rejection (Alvarez-Pereira et al., 2015).

Furthermore, econometrics are generally inappropriate for considering aggregation mechanisms: Most of the studies use either exclusively aggregated macro variables (in a macroeconomic framework) or micro variables (in a microeconomic framework) without considering the important interplay between both (Chen, Chang, & Du, 2012, 02). The systemic analysis attempted by socio economists requires a systemic perspective that explicitly considers the mechanisms between micro and macro levels, i.e. aggregation and downward effects. Aggregation represents a particular challenge to econometrics if the system under investigation involves heterogeneous agents (i.e. almost always). Delli Gatti et al. (2007) shows how many standard econometric concepts, including Granger causality, impulse-response functions of structural VARs and cointegration, lose their explanatory power and spurious results emerge as a consequence.

ABM can be helpful to address these shortcomings:

Considering the problem of inadequate estimation techniques as in the case of the Kuznets

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<sup>15</sup>The extensive survey of Chen (2012) shows how different types of agents can be implemented within the ABM framework. The range of possibilities starts with zero-intelligence agents that may not be of primary interest for social economists, but also include elaborate artificial intelligence agents that require a lot of effort to be built. The adequate conception depends on the problem at hand. The important lesson for social economists is that a very detailed description of agency is possible.

curve, much confusion stems from the fact that many econometric studies are theoretically ad hoc. The underlying models often consider only a single ontological level or are based on static rather than dynamic models. It is therefore often not clear what time horizon has to be considered and which kind of data is adequate for the empirical assessment. We have shown in Alvarez-Pereira et al. (2015) how ABMs can provide the missing formal theory to diminish these problems: Adequately specified they make clear statements about the time horizon to be considered and they help to condense the aggregation effects in the data. In this regard, Chen et al. (2012, 02) suggests to use ABM as a data generating mechanism in order to assess the consistency of the econometric tests: If estimations both for individual parameters and the aggregated data are both consistent, the model has been adequately specified. Without the help of an ABM this consistency remains simply assumed and adverse results emerge.

Lastly, ABM can also help to scrutinize the empirical validity of theories on different levels: As has been argued above, ABMs are subject to micro- or meso-calibration. If a theory gets formalized through an ABM, the resulting model can be tested against the data not only through its overall result, but through the different mechanisms within the model. This facilitates both the construction and the assessment of explanatory theories.

## 5.4 Classification and Discussion

In the preceding sections I have presented formalisms that were (or should) seriously be considered by the socio-economic community. I will now compare them regarding their potential fields of application and their ontological and epistemological tendencies. An overview is given in table 5.1.

### 5.4.1 Frameworks, Theories, and Models

During this discussion I build upon Ostrom (2011) and her distinction between frameworks, theories and models: A *framework* represents a general set of variables and certain general relationships among these. It also provides a metatheoretical language with which one can reason about these variables and relations. This language also helps to distinguish and discuss different *theories* which put their focus on different parts of the framework and suggest more specific assumptions that help to analyse the variables, their relations and the system as a whole more precisely. One framework can therefore be compatible with different theories, which then accentuate different parts of the framework and suggests different interpretations. *Models* then involve very specific assumptions about some of the elements of a theory and are used to derive precise predictions or explanations for these variables. Different models can be derived from the same theory and implemented within the same framework.<sup>16</sup> In our context, some preliminary

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<sup>16</sup>For Ostrom, examples of theories are *game theory*, *public choice theory*, *transaction cost theory* and the like. I define theory in a broader sense such as the *neoclassical* or *institutionalist* theory, but this is not of crucial

	<b>SFM</b>	<b>IAD</b>	<b>System Dynamics</b>	<b>Game Theory</b>	<b>ABM</b>
Type	Framework (Model)	Framework	Model	Model	Model
Ontological Tendency and Compatibility	Holistic	Individualistic	Holistic	Individualistic	Systemic
Epistemological Tend. and Compatibility	Holistic	Individualistic	Holistic	Individualistic	Systemic
Compatibility	SD, ABM, GT	GT, ABM	SFM	ABM, IAD	SFM, IAD, GT
Remarks	Usually used as an overall frame, but potentially as a general model of one system on its own. Interpretation as a digraph allows a most detailed scrutiny of policy implications.	Extremely flexible, not limited to OIE; a systemic consideration possible if a flexible and dynamic model is used within the action arena. Thus, it is very much dependent on which models are used to enrich the framework.	Can be used for empirical assessment of theories and is a good choice if mainly macro or meso variables are to be considered. Especially useful for creating policy advice.	Requires much interpretational effort and strong embedding into theory	Very flexible tool compatible with many theories and frameworks. Can be used as a complement to econometrics to assess theories on different ontological levels and is very useful to study aggregation problems (esp. upward and downward causation).

Table 5.1: An overview of the different formalisms.



questions immediately arise: Which of the above described formalisms falls into which category, and how does this relate to the relationship among the different formalisms?

The answer is obvious for the IAD: It is the canonical example of a *framework*. The variables and relationships within the IAD can be further specified using different models, and depending on the choice of the models, the overall study gets a more socio-economic, neoclassical or different flavor. The IAD is not bound to a specific theory: There are examples of very orthodox applications of the IAD with very strong assumptions regarding the individuals in the interaction arena and the external variables as purely exogeneous. But there are also examples of studies using the IAD within a systemic analysis of the problem at hand, considering important external variables to be endogenous and to use more realistic models for the action arena. Still, the IAD suggests by its design a certain epistemology and ontology, as discussed below.

The SFM is usually used as a framework: As already mentioned, it helps to structure the ideas of the researchers and to express the different variables and relationships of the system under investigation. The specific relations can then be further studied using different, more specific models. Radzicki (2009) shows this for the case of system dynamics: The SFM provides a general overview, and the relationships are then expressed via differential equations, giving rise to a system dynamic model. But an SFM could also, in theory, be used as a model: If the variables are defined in a very narrow sense, and the matrix represents a very definitive and closed system, the SFM becomes a concrete model. But such cases are rather an exception than a rule.<sup>17</sup>

For the other three formalisms, the answer is straightforward: ABM, SD, and GT all represent concrete models. All of them require the researcher to make very clear assumptions and to focus on certain relationships suggested by a more general theory. ABMs for example are compatible with different theories and represent a very flexible modeling tool that can be used to model various situations from very different perspectives. But the single ABM is nevertheless a very concrete model with specific assumptions and a concrete aim.

The grouping of the formalism into frameworks and models suggests seeing them as potential complements, rather than strict substitutes: A model might be used within a framework, so the two formalisms may not be mutually exclusive. This might be true in some cases. But the next section shows that all of the formalisms carry implicit epistemological and ontological tendencies that might be incompatible with each other and prevent a fruitful combination.

### 5.4.2 Ontological and Epistemological Tendencies

For the ontological and epistemological tendencies I distinguish three ideal cases: systemic, individualist or holist tendencies. The technical design of all the formalisms suggests a certain

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importance. I agree that the theory suggests the parts of the framework that are given particular importance.

<sup>17</sup>This shows that a clear-cut distinction between the three ideal types is not always possible. Also, different researchers apply the formalism in a different manner. Still, they may be useful as a general taxonomy which facilitates to think about formalisms and their application.

approach. If this *tendency* is not adequately reflected, it will stay unrecognized, with significant consequences for the outcome and the interpretation of the study.

I speak of an individualist tendency if the model or framework focuses on individual agency to explain the phenomena present at various levels of the system under investigation. The distinction between an ontological and an epistemological individualism is the following: While the individualist ontology suggests the absence of anything such as a ‘social whole’, the individualist epistemology does not deny such a social whole, but it denies the possibility of learning anything about a system by considering this “social whole” directly. All relevant information on the system can be gained by the exclusive study of the individual level. von Mises (1949) advocates an individualist ontology when he argues that “a social collective has no existence and reality outside the individual members’ actions.” A form of epistemological individualism is articulated by John Hicks when he praises Leon Walras for having understood “that the only economic explanation of a phenomenon is its reference back to individual acts of choice” (Hicks, 1934, p. 348).<sup>18</sup>

A holistic tendency means that a model focuses on the relationship among macro variables, as the societal whole is assumed to transcend its individual members. What happens in the system is the consequence of emergent properties of the system that cannot be explained from the individual level. Again, an epistemological holist would not question individual agency, but argue that individual actions are determined by macro variables alone. Studying the latter already tells one everything about the former. An ontological holist would go further and deny the existence of individual agency at all. Recent examples of a pure ontological holism are hard to find. Durkheim, with his focus on social facts and his concept of an organic society, is sometimes used as an example. Some also consider Marxism to be an example of ontological holism, although there is an ongoing dispute on this subject.<sup>19</sup>

Systemism can be considered to be the ‘golden middle’ between individualism and holism: Here the whole system is considered to be a composition of different sub-systems that possesses both reducible and non-reducible properties. Individual behaviour both shapes and is influenced by its environment: Both downward and upward effects play a role. For the ontological systemist, there are different ontological levels within the system under investigation and all of them contain relevant mechanisms and properties. Such a *layered ontology* is an essential part of the Darwinian interpretation of institutionalism elaborated by Hodgson and Knudsen (2010). Similarly, according to systemist epistemology one has to study all levels of a system and the

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<sup>18</sup>Hodgson (2013b) rightly points to the confusion that is often associated with individualism when he discusses the meaning of methodological individualism. Whether individualism includes the relation among individuals has never been clarified. I think that the constituent element of individualism in any sense is the denial of downward effects on individuals. This is in line with Kapeller (2015), who identifies this denial with a *simple fallacy of aggregation*.

<sup>19</sup>Some passages of Marx suggest a clear holist ontology, e.g. his statement that “the capitalist functions only as personified capital [...] just as the worker is no more than labour personified.” (Marx, 1982, p. 989). But there are also other examples, e.g. the notion that “history is nothing else than persons pursuing their aims.” (Marx & Engels, 1956, p. 125).

corresponding relationships in order to fully understand the system, both as a whole and in its different parts. Such a view has been put forward e.g. by Bunge (2004).

**Game Theory** Regarding the underlying ontology, game theory is the most rigid formalism: It is certainly rooted in individualist thinking. Still, game theoretic models can be useful for a systemic analysis if they are interpreted adequately. But such an interpretation requires certain effort, as Elsnar (2012) has argued extensively. There is a clear epistemological tendency towards individualism as the only endogeneous driving force in the model is the individual, and a compatibility with a systemic epistemology can be achieved only if downward effects are included via the rules of the game. GT is certainly not compatible with either holistic epistemology or ontology.

**System Dynamics** At the other end of the spectrum we have system dynamics models: Although certain individualistic variables can be included into the models, they mostly work with aggregated variables, and the interaction among the agents on the micro levels is not modelled explicitly. So while SD can be made compatible with a systemic ontology or epistemology, such a specification is not directly suggested by its technical design. In any case, SD is incompatible with both individualistic ontology and epistemology.

**Agent Based Models** ABMs are somehow in the middle, with a certain tendency towards individualism: Agents are considered to be actors and one of the driving forces behind the dynamics in the system. Nevertheless their behaviour and state can depend on the state of entities on a higher ontological level, e.g. groups or the whole population. As was shown above, systemic concepts such as reconstitutive downward causation can be considered in ABMs. Still, there is some tendency towards individualism as the systemic processes must be actively included into the models, while the upward effects from the micro to the macro level are naturally present in any ABM, just due to its technical design.<sup>20</sup>

A danger of ABM is thus that one tunes the behavioural rules of the individuals in such a way that the desired macro behavior gets deduced from the individual actions - such a specification is not necessarily realistic, especially if there is clear evidence for other ontological levels playing a role. Such a failure can be prevented if all the decision making procedures and other mechanisms in the models are made subject of empirical assessment.

**Social Fabric Matrix** The SFM-A has a holist tendency, as individual decision making is usually not directly included into the matrices. The focus is mostly on aggregated variables and some influential institutions. Thus, the existence of different ontological levels is acknowledged and frequently considered. But the behaviour of different individuals or emergent phenomena

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<sup>20</sup>In fact, theory is required to allocate the different objects of the ABM on different ontological levels. Technically, an agent is as much an object as an institution. That the latter belongs to a different ontological level must be inferred from the underlying theory.

triggered by the interaction of heterogeneous individuals are usually not modeled explicitly. It seems therefore fair to say that the SFM-A has a holist tendency, at least concerning its epistemology. But it can successfully be used for a systemic investigation as well, especially if it gets enriched by ABMs to consider aggregation problems and the role of individual agency explicitly.

**IAD** To the same degree at which the SFM fosters holistic perspectives, the IAD has a tendency to favour individualistic studies. This is due to the focus on the interaction arena. But the character of the study depends in the end very much on the model that is used within the interaction arena. If one models the interaction arena via a game theoretic model and assumes the external variables to be exogenous, one ends up with an individualistic study. If the interaction arena is modeled using a more sophisticated ABM and the external variables and considered endogenously, the resulting study is clearly systemic. The general tendency of the IAD is therefore in the individualist direction, although it certainly allows for systemic accounts if the models for the interaction arena are chosen accordingly. It is not compatible with either holistic epistemology or ontology.

### **5.4.3 The Relation among the different formalisms**

The above shows that the formalisms are not necessarily substitutes. In particular, frameworks are usually accompanied by a model. But not all the models can be fruitfully employed with all frameworks. Their ontological and epistemological orientation must fit together. Furthermore, depending on the question at stake, different models may be the adequate choice. So, while models and frameworks are no substitutes, different models and different frameworks are not always competing with each other directly: SD models are predestined if there are some macro variables of interest that influence each other according to rules that can adequately be expressed via conventional differential equations. As argued extensively by Radzicki (2009), SD models can effectively be used to supplement analysis within a SFM. This combination has led to very interesting results, e.g. in Hayden and Bolduc (2000). Because SD is an approach focused on aggregate variables and relationships, it is only of limited value within the IAD framework, as it cannot be used intuitively to model the interaction arena which is mainly concerned with the decisions on the micro level.

ABMs are to be preferred over SD models if either individuals can be expected to be the driving forces of a system or if entities from different ontological levels are expected to interact with each other and aggregation is thus not necessarily straightforward. ABMs are also a good choice if one has more precise information or hypothesis about the heuristics according to which individuals make their behavioural choices: Often, these heuristics can be expressed much easier via algorithms than via conventional equations, and their role for determining the dynamics of the whole system can be explored.

Because they allow a very detailed representation of real world systems and thus allow the explicit consideration of various mechanisms and their interplay, ABMs are very well suited to model the interaction arena within the IAD framework. They might also be useful to complement a SFM, especially if the SFM includes nodes from different ontological levels and a system dynamics model is thus more difficult to implement.

Both SD and ABM can be used to conduct artificial experiments and thus to effectively generate policy advice. Also, both models can be used to complement and qualify econometric assessment of different hypotheses. Again, ABMs are to be preferred if one wishes to assess the role of aggregation and (reconstitutive) downward effects within the system. SD should be used if there are reasonable information about the relation of macro variables, but a specification of micro mechanisms would involve considerable speculation. Especially if predictions for alternative policy measures are to be derived, this would be a strong argument in favour of SD.<sup>21</sup>

Game theory is a prominent choice if it comes to modeling the interaction arena within the IAD. Numerous examples have proven the effectiveness of this combination from an orthodox viewpoint, although the resulting models can be considered only partial successes if considered from the perspective of socio-economics: As both the IAD and GT have individualist tendencies, their combination will most likely fail to provide an inspiring study of a societal system as a whole.

Also, if considered in combination with the SFM, GT can be very useful to illustrate a relationship between two nodes in a qualitative manner, especially if the two nodes are on the individual and/or the meso level. The embedding into the broader context of the SFM-A effectively addresses the shortcomings of game theory and facilitates a systemic interpretation of the model outcome and the rules of the game. Furthermore, within the broader perspective of the SFM-A, practical policy recommendations can much easier be derived than in the rather abstract GT models alone. If the game becomes too complicated to be solved analytically, it can easily be implemented in an ABM framework: Especially GT models involving a topological structure or many heterogeneous agents are solved numerically within an ABM. This is particular attractive for socio-economic analysis as it allows a further relaxation of the otherwise rigid assumptions in game theoretic models.

The last question is whether the SFM and IDA can be fruitfully used together. The only cases in which this could be is if the SFM helps to identify important relationships between the external variables with key variables in the interaction arena of the IAD, or if one uses a very specific SFM within the IAD, either to clarify relevant dynamics within the set of external variables or between external variables and the interaction arena. Both cases are theoretically possible, but practically irrelevant. Even if the possibility exists, there are probably much more intuitive ways to model the corresponding system than to artificially bunch two frameworks together that come from, while not contrary, but different perspectives.

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<sup>21</sup>Scholl (2001) argues for a certain complementarity among SD and ABM: They give insights to the same system from different perspectives. This does not affect the argument that they are not to be used simultaneously together.

## 5.5 Conclusion

This paper has presented different formalisms that can help socio economists in their scrutinies. It is clear that neoclassical theory exaggerates the use of formalisms, but is by no means representative for formalist analysis. All the formalisms discussed in this article can potentially be useful for socio economic analysis, but to achieve this, the formalism must be embedded into a broader theoretical frame: No formalism speaks adequately for itself. All have to be interpreted, and their inherent ontological and epistemological tendencies have to be reflected. This article therefore represents a potential starting point for a more extensive and adequate use of formalisms in this sense. Much can be gained from such an application: Formalist analysis can allow the consideration of questions that have not yet been dealt with (e.g. the role of empirical network structure on societal dynamics) and existing arguments can be made more precise.

To conclude this paper, let us consider the question whether some of the formalisms outlined here can help to bridge socio economic (of heterodox analysis more generally) with more orthodox work. This might particularly be the case for the IAD framework or game theory, as these are also employed by neoclassical economists. Besides the question about how much can be gained from such a dialogue, there should not be too much hope put into the employability of the formalisms discussed in this article: The fact that a certain framework or a way of modeling is compatible with different theories still does not exclude the possibility that the resulting studies are incommensurable: ABMs for example are compatible with a wide range of different theories, including neoclassical theory.<sup>22</sup> But different ABMs might not only yield very different results, they are very different to compare. Their underlying ontologies might be entirely different, the one model might be designed as part of an explanatory exposition, the other model as a self-sufficient device for prediction. While both are models of the same type, they have nothing else in common and can impossibly mutually advancing.

The more important message of this article, however, is delivered through the exposition of cases where formalisms are essential for further progress in socio economic analysis and the motivation of their reflected and adequate application in the future.

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<sup>22</sup>One could argue, for example, that neoclassical DSGE models are nothing else but very specific ABMs.

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# Appendix A

## Personal contributions to the papers of the cumulative dissertation

### **New Perspectives on Institutional Pattern Modeling: Systemism, Complexity, and Agent-Based Modeling**

This paper was joint work with Jakob Kapeller, head of the *Institute for Comprehensive Analysis of the Economy* (ICAE) at the Johannes Kepler University Linz, Austria. The idea emerged before the 2015 ASSA conference in Boston where we both presented papers that had a clear relation to systemism in the title. We therefore decided to show the complementarity of our approaches in this joint paper.

My main contribution was to point out the relation of systemism to traditional institutional pattern modeling (in particular considering the work of Wilber & Harrison and Myrdal), the relation to the theory of economic complexity, and the methodological link to agent-based modeling. Jakob contributed by explaining the relation of systemism to social sciences and heterodoxy in general.

### **The micro-macro link in heterodox economics**

This chapter was also joint work with Jakob Kapeller and is a contribution to the *Handbook of Heterodox Economics* (edited by Lynne Chester, Carlo D'Ippoliti, and Tae-Hee Jo). The handbook will be published by Routledge and will appear in late 2016. The paper was written jointly right from the beginning and it is difficult to disentangle our contributions. Jakob mainly contributed the idea of different compositional fallacies and suggested the overall structure of the paper.

I contributed all formal arguments, the majority of the section on relations, and the concrete modeling examples throughout the paper. The discussion of mechanism-based explanations as a crucial part of systemism was also mainly my own work.

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## **Agent-Based computational models - A formal heuristic for institutionalist pattern modelling?**

This chapter was written by me as a sole author and is based on my own ideas. Of course, I am grateful to the people mentioned in the acknowledgments and participants of the conferences where I presented this paper.

## **Formal Approaches to Socio Economic Analysis - Past and Perspectives**

This chapter was written by me as a sole author and is based on my own ideas. Of course, I am grateful to the people mentioned in the acknowledgments and participants of the conferences where I presented this paper.

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# **Appendix B**

## **Erklärung über die Anfertigung der Dissertation ohne unerlaubte Hilfsmittel**

Ich erkläre hiermit, dass diese Arbeit ohne unerlaubte Hilfe angefertigt worden ist und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt wurden.

Ich erkläre ferner, dass die den benutzten Werken wörtlich und inhaltlich entnommenen Stellen als solche kenntlich gemacht wurden.

Bremen, 12. Januar 2016

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Claudius Gräbner