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

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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 for joint research under the methodological umbrella of ABM.

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)[1] can provide a useful formal extension to the research program of original institutional economics (OIE).[2]

[1] 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 to analyse the outcomes are crucial. While I have much sympathy for this idea, I here stick to the most common acronym, ABM.

[2] 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.

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ABMs are commonly associated with the rising research program of complexity economics.[3] 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 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).

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. The main potentials and dangers of ABM are discussed in Section 4. Section 5 concludes and points to directions for future research.

[3] Although not all complexity economists agree to the use of ABMs, see e.g. Durlauf (2005).

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 behaviour 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 and Fagiolo, 2007).

ABMs also allow the natural inclusion of institutions, rules and networks. These phenomena are often subsumized under the meso level of the economy, because they affect an emerging subset of the whole population (Elsner and Heinrich, 2009).[4]

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 neighbours, 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.[5] 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 and 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 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 mechanisms 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] Such a notion of "meso" is slightly different to what meso means in the "micro-meso-macro" framework of Dopfer et al. (2004), where a meso unit is a social rule and all its actualisations. But this notion of meso can also be implemented in an ABM. Dopfer and 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."

[5] 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.

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 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.

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 and 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 and 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; Hodgson, 2006; Hodgson, 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 and 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 behaviour" (Arthur, 2006, p. 1553). This is the same as to say that "parts are at once conditioning and conditioned by the whole" (Wilber and 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.

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.[6] 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 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.[7] 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 Knudson (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

[6] For a more detailed exposition of Bunge's systemism and its usefulness for economists see Kapeller (2015 forthcoming) and Gräbner and Kapeller (2015).

[7] 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.

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 and Knudson, 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.

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.[8]

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.

[8] 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).

But recent studies of networks showed that small-world or scale-free networks are ubiquitous in reality.[9] 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 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.

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-

[9] The issue is much more complex than presented here and empirical networks should be described more precisely using different statistics. For the general argument, however, the following rough outline suffices. See the excellent (and freely available) introduction to network theory of van Steen, 2010) for further details.

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 et al., 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:[10] One starts with concrete case studies and then expresses the verbal arguments rigorously in a formal language. For such purposes, the 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 flavour 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 and 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 and 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).

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

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 oeconomicus* 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.[11]

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.[12] More sophisticated decision procedures could be included using genetic algorithms. Genetic algorithms represent heuristics that help to solve optimization problems in a satifsactory 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.

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

[11] Velupillai and Zambelli2011) 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.

[12] 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.

playing an important role (Radzicki, 1988; Heap and Varoufakis, 2004; Vilena and 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.

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 Knudson (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 the use of 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. Discussion

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 et al., 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 and Axtell, 1996).

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 sceptical 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.[13]

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.

4.3 ABMs are compatible with the Institutionalist approach

[13] 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.

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 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.

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[14] 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 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.[15]

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 (2014) and Wäckerle et al. (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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[14] http://www2.econ.iastate.edu/tesfatsi/ace.htm
[15] http://www.complexityexplorer.org/

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