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Abstract

Institutionalist economists have always been criticizing the neoclassical way of studying the economy, especially because of its obsession to a very strict and flawed formalism. This formalism receives critique also from advocates of agent-based computational economic (ACE) models. The criticism seems to be similar to that of institutional economists. Although some authors consider ACE models to belong to a completely new way of thinking about economics, many concepts of ACE have been anticipated by institutionalists: Although using a different vocabulary, ACE proponents speak about cumulative causation, realistic agents, explanatory models, dynamic relations among individuals and the necessity to see the economy as an systemic whole rather than from an atomistic perspective. Consequently, the emergence of the ACE framework may not be left unconsidered by institutionalist economists. This paper investigates the consistency of ACE models with the institutionalist research program as defined by Myrdal, Wilber and Harrison and other original institutionalists and discusses whether ACE models can be a useful heuristic for institutionalist "pattern modelling". I study the ability of ACE models to provide a holistic, systemic and evolutionary picture of the economy, the conception of agents in ACE models, and ask whether they can help to understand the social stratification of a society with its power relations. I also compare ACE models with earlier attempts to formalize institutionalist analysis, e.g. by Bush and Elsner (Theory of Institutional Change), Hayden (Social-Fabric-Matrix) or Radzicki (System Dynamics).

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1. Introduction

Institutionalist economists have always been criticizing the neoclassical way of modelling the economy, especially because of its obsession to a very strict (and seriously flawed (Keen, 2011)) formalism, which was taken over from 19th century physics to determine a "perfect market" equilibrium. This formalism receives critique not only from institutionalist economics, but also from a growing number of researchers advocating a more extensive use of agent-based computational economic (ACE) models. At a first sight, their criticism of the "analytical straitjacket" of neoclassical economics (Farmer, 2012) seems to be very similar to that articulated by institutionalist economists, but one quickly recognizes that the advocates of ACE models are themselves a highly diverse group. While some of them consider ACE models to be an interesting extension to neoclassical economics (e.g. Durlauf (2005)), others consider them to belong to a completely new way of thinking about economics (Arthur, 2013). The relation between OIE and ACE is, however, largely unknown. Many concepts of ACE, though, have been anticipated by institutionalists: Although using a different vocabulary, ACE proponents speak about cumulative causation, realistic agents, explanatory models, dynamic relations among individuals and the necessity to see the economy as an organic whole rather than from an atomistic perspective. Consequently, the emergence of the ACE framework shall not be left unconsidered by institutionalist economists.

This paper investigates whether the use of ACE models is consistent with the research programs of institutionalist economics as it is defined by Myrdal (1978), Wilber and Harrison (1978) and other institutionalists. After giving a short introduction to the ACE framework, I will study the ability of ACE models to provide a holistic, systemic and evolutionary picture of the economy in Sections 3.1 and 3.2 respectively. I then study the conception of agents in ACE models in Section 3.3 and ask whether their can help to understand the social stratification of a society with its power relations in Section 3.4. ACE models are not the first formalism proposed for or developed in institutionalist economics. I review former attempts in Section 4.
In Section 5 I compare ACE models with the other approaches and discuss whether OIE can profit from ACE models. Section 6 concludes and points to directions for future research.

2. What Agent-Based-Computational Models are about

ACE models are the computational study of economic processes modelled as dynamical systems (Tesfatsion, 2006, p. 835). What seems to be very technical at the first sight, is in fact a very intuitive tool to represent and understand the dynamics of a societal system. Here I focus on the general idea behind ACE models. The interested reader might consult appendix A for a more technical description of the formal structure of ACE models.

ACE models differ from the strict analytical-mathematical 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, but allow a *realistic* representation of the system under investigation in the sense of an evolutionary science according to Veblen (1898).

The basic idea is to specify the fundamental entities (esp. the economic agents) in a reasonable manner and then to study the systemic and dynamic consequences of the configuration. Because the resulting system is usually very complicated, one relies on simulation to solve the system. Logically one proceeds from the assumptions about the entities to the conclusions regarding the overall dynamics. This contrasts the practice in general equilibrium modelling (esp. Computable and Dynamic Stochastic General Equilibrium (CGE, DSGE) modelling), where one has to specify the behavioural assumptions not solely on their adequateness, but also whether they are suitable to yield a stable equilibrium for the overall dynamic.

In this regard, ACE modelling is not bound to the dubious epistemological (and ontological) perception of neoclassical economics based on Friedman (1966) that does not emphasize the realism of the model assumptions, but only focuses on the aggregate outcome of the model: ACE models can be built realistically on the micro, meso and macro levels:

If one considers the economic agents to represent the micro level, ACE models 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. More generally, ACE models 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, as it is specified by the underlying, possible changing, network structure. As the agents (such as the rest of the model) do not have to be represented via convenient equations but are more intuitively specified via a computer language, a model can be (of course, depending on the programming language used) quite readable even for a non-trained reader. And, to specify the agents in such a way allows the natural implementation of heuristics, learning behaviour and habits.

On the meso level, ACE models allow the natural inclusion of institutions, rules and networks (Elsner and Heinrich, 2009; Elsner et al., 2014). It is therefore straightforward to study phenomena such as reconstitutive downward causation in these models (Hodgson and Knudsen, 2004). Additionally, as the interdependence of the economic agents is modelled explicitly via the underlying network structure, group formation and dynamic power relations among the agents can explicitly taken into account. Agents can also be capable of communicating with each other and to hide or share information with each other, with important consequences for the overall dynamic of the system (Moss, 2002).

The macro dynamics of the system are therefore the result of the aggregated behaviour of direct interdependent agents. It is not surprising that this kind of models are particularly prominent in the complexity economics research program that interprets the economy as a complex system, i.e. a system made up from many heterogeneous, direct interdependent and adaptive agents (Elsner et al., 2014). Although some see the complexity research program to be a mere extension to neoclassical economics (Durlauf, 2005, p. F225), leading figures of the field consider it to be "a different way to think about economics" (Arthur, 2013). If one takes the positions of the latter group, one recognizes that many conventional methods are rejected as being to restricted and seen as a straitjacket that hinders a full understanding of the economic system (Farmer, 2012).[1] In contrast, ACE models are considered to be flexible enough to get a better insight into the functioning of the economy (Farmer and Foley, 2009).

ACE models are therefore suited for an analysis contrary to the reductionist view of neoclassical economics, where models must derive their results from the behaviour of rational agents.[2] It is therefore an important question whether ACE models can be of interest for institutionalist economists as well, and if so, to what extent and how. This is what I am going to review in the following sections.

3. ACE models and the methodology of OIE

The tradition of OIE has its direct origins in the work of Thorstein Veblen, John R. Commons and Gunnar Myrdal among others.[3] Right from the beginning, institutionalist economists distinguished themselves as critics of neoclassical economics. But because the critique of the dominant approach to economics has always been an important aspect of institutionalism, it is not straightforward to identify the methodological core of this vital research program.

A very good starting point, however, is the classical paper of Myrdal (1978) under the heading "What is institutionalism?". In the same year, Wilber and Harrison (1978) published a paper about the methodology of institutionalist economics in which characterized the institutionalist way of modelling as *pattern modelling* in which he

[1] While it is frequently argued that the important aspect neglected by neoclassical economics are *emergent properties*, some argue that many central results of neoclassical economics such as the welfare theorems describe themselves emergent properties (Blume and Durlauf, 2001). I argue in Section 3.1.2 that while neoclassical economics might handle emergent phenomena in the context of systems with disorganized complexity, it is not able to handle the much more interesting emergent phenomena in systems characterized by organised complexity. When referring to emergent properties I therefore mean emergent properties in the context of systems with organized complexity.

[2] This does not mean that ACE models cannot be used for neoclassical modelling as well. As it is a very flexible tool, it could even be (mis)used to draw a picture of the economy consistent with the reductionist and constructionist worldview of neoclassical economics.

[3] The indirect roots go back in history of course. Veblen received important influence from pragmatist philosopher Charles Peirce (Hall and Whybrow, 2009).

comes to very similar answers like Myrdal (1978). The criteria identified by the authors are still representative for the way most economists identifying themselves as original institutionalists work and I will use them as a starting point for the question of whether ACE models can play a role in institutionalist economics today. Some additional criteria will be added at the end of the section.

Wilber and Harrison (1978) identified five important characteristics of the models built by institutionalist economists: they are necessarily *holistic*, *evolutionary* and *systemic*, and they pay particular attention to *conflict and power relations* within a society while being based on a *realistic conception of economic agent* and therefore reject the models based on the neoclassical conception of rational individuals.

3.1. Holism and Systemism

Wilber and Harrison (1978) explicitly distinguished between *holism* and *systemism*. For them holism, which is considered to be the opposite of *atomism*, entails a focus on the pattern of relations among the agents and the economy as a whole (Wilber and Harrison, 1978, 71). Such "holistic" theories therefore share 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. 74). Systemism, as used by the authors, means that the economy is expected to show patterns that emerged from the joint behaviour of the agents but that cannot be derived from the behaviour of a single agent in isolation. In an adequate model, the parts of the system under investigation must make up a coherent whole and must be understood in their relation to the whole (Wilber and Harrison, 1978, 71).

Their distinction between holism and systemism seems not to be entirely adequate. In the philosophy of science, holism most often means to understand the society as a whole, but nothing but the whole. 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 and Veblen himself stressed the individual's instinct of workmenship and their idle curiosity. Such concepts are worthless to the holist as they would be mere derivatives of the social structure in which the individuals exist.

It is noteworthy that the authors spend considerable more time and space on their elaborations on holism than on systemism, which they use only three times (however, in very exposed situations). This is probably due to the fact that the latter concept was not very well elaborated in their times.

Their crucial message of systemism seems to be that the different parts of the economy must make up a coherent whole, while they use the the concept of holism to argue that both the relations among individuals and the relation between different ontological levels of the economy are important. These two messages are, however, closely interrelated and it seems not clear how the two concepts exctly differ. In the end, it is not important what claim they attached to which label, but to understand their overall messages:

Firstly, they stress the mutual interdependence of different levels in the economy, an idea that is most precisely articulated in the institutionalist concept of *reconstitutive downward causation*. Secondly they want to stress the importance of the relations among the individuals in the economy and the consequences of these relations for the economy as a whole. Another way to state this is to claim that the society is characterized by *organised complexity*. I will elaborate on these two clams in Sections 3.1.1 and 3.1.2 respectively. I then conclude this paragraph by showing that it is modern systemism that best describes the institutionalist perspective on the economy. Particularly I show that their rejection to take parts of a system out of their environment and to study them in a limited context is shared by modern systemism and that Wilber and Harrison (1978) would have chosen this term to describe institutionalist pattern models if they had written their article today.

3.1.1. Mutual interdependence of different system levels

While neoclassical economics require all models to be microfounded in the sense that the whole must be understood by reducing it entirely to the level of its individual parts (and is therefore to be classified as an individualistic framework), institutionalist models try to explain the whole by its parts, but not by the parts in isolation but by their interaction with and by their inter-relation to the whole itself.

The authors probably have chosen the term holism to reject the atomism represented by neoclassical economics, as the opposite of atomism is indeed *holism*.

But this does not mean that the study of individuals should give place to the study of the whole entirely. Rather, the study of individuals, groups and the entire population are strongly interconnected and none of the three can be successfully understood without considering the other two. Or, in the words of Wilber and Harrison (1978, 71): "The process of social change is not purely mechanical; it is the product of human action, but action which is definitely shaped and limited by the society in which it has its roots."[4]

Institutionalists use the concept of *reconstitutive downward effects* (Hodgson, 2002, 2006, 2011) to account for the fact that different ontological levels of the economy are strongly interdependent, and that patterns emerge because of their interrelatedness. These patterns, which can be considered to be *emergent phenomena*, then shape the consciousness and behaviour of the agents on the individual level again. They are independent from the support of the individual agent but can only sustain if they are supported by a critical mass of agents. Because the existence of these effects has its reasons on the lower micro level, but this micro level is influenced by the effects themselves and still necessary for the persistence of these patterns, they are called *reconstitutive* downward effects. Following the current conventions, such a theory would not be termed holistic, but *systemic*. But Wilber and Harrison (1978) use this term to clarify that the parts of the system under investigation must make up a coherent whole and must be understood in their relation to the whole (Wilber and Harrison,

[4] Such an investigation has to go hand in hand with a realistic conception of the human agent. Here I will focus on the ontological implications and deal with the concequences for an adequate specification of the agents, particularly their intellectuual capacities and social embedednes in Section 3.1.2 and especially in Section 3.3.

1978, 71). They made use of the term holism most probably to reject neoclassical individualism, but as was clarified by Bunge (2000), individualism is also rejected by systemism alone. Can ACE models be consistent with a view of the economy that stresses the mutual interdependence of its different layers? Brian Arthur, one of the leading figures of the complexity movement in economics and an advocate of ACE models, described the process in the models like this: "Behaviour creates pattern; and pattern in turn influences behaviour" (Arthur, 2006, 1552). 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 ACE model one specifies the agents and how they behave in certain situations. The trigger for their behavior is generally their own state, but also 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 ACE models.

In recent years, institutionalist have been able to get important insights into the economy and they will continue to do so, even without the use of ACE models. But although they are neither necessary nor sufficient, they can be extremely *useful* for building theories considering the interdependence of the different levels of the economy. Take the concept of reconstitutive downward effects as an example. Hodgson himself makes use of ACE models to illustrate the concept (Hodgson and Knudsen, 2004). He does so of course not with the model alone. Rather, the ACE model is embedded in a wider frame of arguments and serves as a complement to the verbal discussion of the system under investigation.

As such models try to be realistic and to be explanatory, they are naturally very complicated. ACE models can help heuristically to check whether the processes elaborated so far are sufficient to recreate a dynamic observed in reality, or whether two proposed aspects have very different outcomes if considered together than if considered in isolation. Especially in this case the use of ACE models can be very useful, be it as heuristics or as *topoi* guiding the questions to be asked by the researcher during the model building process and ensuring a maximum of rigour and transparency.

Another example of where ACE models can be particularly helpful is the study of the society as a self-organizing system without a central control. This is necessary if one considers society from a realistic point of view as no central planning organization such as the fictitious Walrasian auctioneer exists. In this case, one has to deduce the overall dynamics from the interaction of its constituent parts and has to account for the interplay of the different levels, which is exactly what ACE models were invented for.

Finally, such an investigation must go and in hand with a realistic conception of the economic agents. The agents have to face computational constraints and must be socially embedded and ACE models offer a rich set of tools to model agents realistically (see Section 3.3). But most importantly, they force the researcher to think about the agents, their environment and the relation among them simultaneously. The interdependent character of these aspects it therefore naturally represented in the structure of ACE models.

3.1.2. Social systems show organised complexity

As mentioned above, insitutionalists reject the atomistic perception of neoclassical economics according to which the economic agents are homogeneous and interact only indirectly via the price mechanism of the market. But they do not only reject it because they claim the importance of the interrelation among the different levels of the economy, but also because of the importance of the relation among the different entities on the individual level, the economic agents.

A consequence of this is the impossibility to understand the behaviour of economic agents or the economy as a whole if one restricts one's analysis to that of an individual in isolation as it is still common in neoclassical economics. Some might respond that this delineation is not up-to-date any more as modern models of the mainstream include heterogeneous agents and deal with questions of network structure. This objection is misplaced in many ways, but most importantly, although there are many general equilibrium models including either heterogeneous agents[5] or an explicit network structure. But it has been shown that the simultaneous presence of heterogeneity and an explicit network structure poses significant difficulties to general equilibrium models (Page, 2012). It is far from clear how one could deal even with a very basic notion of heterogeneity and interdependence in a general equilibrium framework, that is still representative for the modern mainstream.

The idea underlying the institutionalist conception of the economy and their focus on the relation among the individual components seems to be strongly related to the reasoning of Warren Weaver about simple and complex scientific problems: According to Weaver (1948) *simple* problems only include 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 cannot be studied under the *ceteris paribus* assumption because of the interrelatedness of the variables (Weaver, 1948, p. 537-538). What Weaver has taken for granted is obviously not accepted by many economists who make extensive use of *ceteris paribus* assumptions when studying social systems. Weaver then further 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 theory generally assumes this kind of complexity when it assumes error terms to be identically and independent distributed.

In contrast, a system showing organized complexity shows 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.

The analytical models of neoclassical economics in contrast presume the economy to show disorganized complexity only. Their unambiguous results can only be obtained

[5] Although one can argue about their notion of *heterogeneity*.

by assuming mechanical agents that interact in a linear fashion.

Many ACE models are motivated with the argument that the economy exhibits organised complexity (Miller and Page, 2007). The implementation is straightforward: The use of classes allows to specify heterogeneous agents with the same attributes that interact with each other and their environment. As there is no requirement for the system to exhibit a particular dynamic (esp. an equilibrium path), assumptions can be made on entirely proper considerations. By changing the nature of the agents and their way of interacting, one can easily elaborate whether an emergent pattern is the result of non-linear interactions or not and model the system with an adequate specification without a compulsive formalism, but with the obligation to state any assumed process explicitly.

Because of this straitforward implemenetation, ACE models were already used in recent institutionalist studies about the emergence and persistence of institutions and habits in order to back the argumentation about how institutions come to emerge, persist or dissolve in a framework with non-linear interactions among directly interdependent agents (e.g. Hodgson and Knudsen (2004), Elsner and Heinrich (2011)).

To take the organised complexity in the economy serious entails the possibility of different foci in one's research, i.e. the dichotomy between micro and macro level tends to vanish. To overcome the dichotomy institutionalists started the investigation of the meso size of the economy: The corresponding studies focused on habits, rules and institutions that persist in carrier group smaller than the overall population. Important foci have been the emergence and persistence of cooperation in dilemma-like situations, the persistence of different rules and habits of different groups in the same population and the performance of different organizations and groups and their role for decetralized collective decision making, wealth distribution and social stratification (see below).

ACE models can guide the instututionalist reasoning in the framework of meso economics as they can be helpful in determining the critical group size for an institution to persist and can help to figure out non-trivial connections among the variables in the model (Elsner and Heinrich, 2009; Elsner, 2010).

They can also help to identify properties such as *self-organizing criticality*, which is a property of open (i.e. dissipative) systems without a central control that are characterized by many interacting agents. The concept of self organizing criticality is in the tradition of Granovetter (1985, p. 504) who argues that most economic behaviour is closely embedded in networks of interpersonal relations and uses this argument to criticise neoclassical economics from a sociological perspective. If the agents in an open system are socially embedded, the system is said to show self-organized criticality if the interactions of the agents yield a state of the system that is robust to small changes in the agents behavior, but frequently experiences "avalanches" of change, after the individual interactions cumulated in a specific way. The concept is most famously related to the example of a sandpile to which one can add singe grains without anything happening, but if a certain threshold of grains is passed, many grains fall down the pile (Bak, 1996). An economic example is the study of fluctuations of markets as a consequence of factor-demand linkages among different producers, i.e. agents produce and demand goods simultaneously (Scheinkman and Woodford, 1994). Self-organized criticality cannot be explained with neoclassical theories as neoclassical agents are not socially embedded, are not able to communicate with each other, are utility maximizing individuals, i.e. do not use any heuristics and do not have any thresholds in their decision making process (they adjust their demand for goods as a reaction to a price change of only 0.01 cents), and because the equilibrium concept is incompatible with that of self-organized criticality. Furthermore, self-organized criticality only emerges in open systems, while neoclassical economic focuses on closed systems. Therefore, models studying self-organized criticality were mainly of an agent-based nature and while the concept is heavily used in the natural science (and was frequently proposed by physicists and biologists to understand financial crises and financial markets), its application in the social sciences seems to be negligible. It is, however, an interesting concept for insitutionalists and an example of how ACE models might help to include a concept fruitfully into more general institutionalist theories.

3.1.3. Pattern modelling requires systemism

What Wilber and Harrison (1978) described as holism and systemism must now be considered to be two ingredients of systemism. For them, the holist conception means that the "parts are at once conditioning and conditioned by the whole" (Wilber and Harrison, 1978, 80).

As they do not claim the irrelevance of agency structures, but attach much importance to a realistic conception of the economic agent (see below), they would reject what is today considered to be a holist approach, namely the idea that any investigation of a social system must necessarily follow a top-down approach not considering the role of individuals influencing their environment.

I will now explain that their rejection of the both extremes, namely that only the aggregated structure of a system must be considered, as it is claimed by holists, and to explain everything in terms of the smallest parts of the system, as individualists argue, leads to the concept of (modern) systemism. In their elaborations Wilber and Harrison (1978) stressed two particular aspects of systemism, namely the strong interdependence of different levels (e.g. micro, meso, macro), and the importance of the relations among the economic agents and their social embeddedness. But the general approach of systemism is much broader and, as will become clear from the following remarks, perfectly suited to describe the institutionalist conception of the economy.

The fundamental idea of systemism today is to view *anything* either as a system or as a (actual or potential) component of a system. Furthermore, systems are considered to exhibit certain properties that cannot be identified on the level of their components (Bunge, 2000, 149). This is to say that all systems have some sort of emergent properties and must not be studied as a simple aggregation of the individual parts, which is what Wilber and Harrison (1978) say when they argue for a "holistic" view. But not all properties of a system are emergent. Some are indeed only an aggregation of the individual components. Other are present on a subset of the entire system as well. An interesting question is therefore to what size a bigger system, e.g. the society, can be reduced (or "scaled") without loosing its emergent properties. Emergent properties that are the result of (mainly non-linear) 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 and it is something that can be conveniently carried out via ACE models, as it is typically easy to alter the number of agents in the model and to study the change of the overall dynamics. It is clear that different properties might have different degrees of scale invariance. The degree of scale invariance or event the probability whether a certain property will be present on a higher level, can be dependent on the properties and actions of the individuals, which, as elaborated above, can themselves be partly dependent of the state of the whole. It is this crucial aspect of reality that must stay hidden from the dogmatic holist.

Systemism might be seen as the "pragmatic middle" between the two extremes of individualism and holism. It entails the two crucial factors emphasized by Wilber and Harrison (1978) and certainly would have found their approval if it had already been developed as such in the 70s. Furthermore, ACE models can be helpful in many respects to increase our understanding of the society from a systemic point of view: They can help to understand the scaling behavior of systems, to identify reconstitutive downward effects and point to the self-organizing nature of social systems and important consequences such as self-organized criticality.

3.2. Evolution

Institutionalists have been criticizing the static nature of neoclassical economics ever since. The critique involves the rejection of the rational *homo oeconomicus* (an issue that will be addressed in the next section), the (often implicitly assumed) static relations among the agents and the focus on systems with a stable equilibrium as the unique resulting pattern. Institutionalists try to focus on the dynamics in the pattern of relations (Wilber and Harrison, 1978, p. 71) and the interdependence of relevant factors in the economy without being forced to model the system in a way that an equilibrium path necessarily results.

As an alternative to neoclassical equilibrium analysis they developed concepts such as *circular cumulative causation*, *path dependence* and *reconstitutive downward effects* to explain the overall dynamics of the economy.

ACE models have already proofed their ability to include ever-changing and everlasting change of behaviour (Edmonds, 1999; Arthur, 2006). One reason is their ability to include adaptive and boundedly rational agents using (changing) heuristics and relying on inductive reasoning (see the next section). Another reason is their ability to constitute non-linear dynamical systems that exhibit non-ergodic properties, something that is not possible in current neoclassical models. In this way, they are perfectly suitable to resemble the principle of (circular) cumulative causation and the path dependence of real world dynamics. Because the network structure underlying the direct interactions of agents in ACE models, the role of these relations and their dynamic change can be studied explicitly. Hodgson and Knudsen (2004) is a nice example for the effective use of an ACE model to illustrate the effectiveness of this reasoning.

ACE models can be of particular value in the context of networks: As I will discuss in section 3.4, networks are difficult to discuss in a purely verbal analysis as they are difficult to describe verbally and the relation between network structure and the economic outcomes is usually not intuitive, especially when the network structures are non static, but changing. In this case simulations are a very strong ally in visualizing the processes underlying real-world dynamics.

Finally, because ACE models rely on simulations as a "solution concept" there is no obligation for specifying the system in a way that a stable equilibrium path emerges (see also the discussion about the concept of self-criticality in Section 3.1.2).

3.3. Directly interdependent agents

The evolutionary flavour of ACE models is present not only on the aggregated level: The agents themselves are not static and rational, but are boundedly rational and adaptive. Their reasoning is not necessarily deductive, but, following psychological evidence, can be inductive. They are not isolated representative entities, but active and communicating, socially embedded agents (Edmonds, 1999). Fascinating techniques allow to include the institutionalist perception of the economic agents into ACE models and build truly evolutionary models.

But an adequate representation of the economic agents is not only an important tool to make models evolutionary in the institutionalist sense and to allow for an explicit and dynamic representation of direct interaction (and power relations) in the model economy. It is also important to contrast the instrumentalist use of rational (and often representative) agents of neoclassical economics with a realist representation of the economic actor.

Agents in institutionalist models usually have a thirst for power and adventure, a sense of independence, their motivations include altruism, their instinct of workmenship, idle curiosity, custom, and habit depending on the situation they face. Consumption decisions are explained not by the empty concept of utility maximization, but with concrete motives that frequently contrast the rationality assumptions of neoclassical economics, e.g. via the concept of conspicuous consumption and waste.

Because of the label of ACE it is not surprising that a lot of effort has been put into the development of adequate representation of real world agent in ACE models.

Chen (2012) gives an introduction to the various historical origins of ACE modelling and the different approaches to the representation of economic agents in such models. There are, of course, also instrumental approaches that are less attractive to institutionalists (like zero-intelligence agents). But Chen describes how very elaborated artificial intelligence agents can be used in ACE models as well. An example is the CRISIS project that tries to develop an ACE model of the European Union in order to get a deeper understanding of the financial crisis. As in many ACE projects, the modellers make extensive use of *microcalibration* (see Section 3).

Neoclassical economics have never been interested in the realism of their agents which is why they generally reject microcalibration. The utility-maximising homo oeconomicus was built in a way such that mathematical analysis gets as easy and intuitive as possible. Departing from the standard utility-maximizer, the preference relations become more and more complicated and dynamics were introduced by allowing agents to maximize their utility inter-temporary. This is a sad example of what Fontana (2010) recently termed the "oil-spot dynamic". When the unrealistic conception of the economic agent by neoclassical economics received more and more critique, most prominently by Herbert Simon and his conception of bounded rationality, neoclassical economists reacted by building more and more complicated utility functions including *social preferences* or by making the optimization problem more complicated by adding certain "decision defects".

What really was the essence of Simon's ides of bounded rationality is that agents do not have the capacity to maximize their utility and therefore will never do so. They will employ heuristics to cope with the complexity of their environment, rely on institutions and make their decisions more inductively than deductively.[6]

Especially the work of Herbert Simon highlighted how adequately the reasoning of humans can be represented via computational machines. The results has been important for psychologists and logicicists since Simons "logical theorist"[7] and studies such as Lindgren (1992) investigating the continuous change of strategies in an evolutionary environment with constantly adapting agents suggest that these tools can profe extremely useful for institutionalists investigating how institutions form, sustain and persists depending on the nature of the agent population.

One particular useful tool in this respect are *genetic algorithms*. A genetic algorithm is a heuristic that helps to solve optimization problems in a *satifsactory* way. They are applied if a straightforward solution to an optimization problem is not feasible. A genetic algorithm 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. Our organic world is full of examples of genetic algorithms. They can explain very well how certain instincts and behavioural habits have come into existence (Mitchell, 1999, p. 135).

When employed to agents, we can simulate the learning behaviour and their way of adapting to the environmental requirements of agents. This is one source for the ability of ACE models to describe non-reversible dynamics and thus to resemble the principle of (circular) cumulative causation and the path dependence of real world dynamics. The application of genetic algorithms always involves the danger to "get stuck" with bad solutions, i.e. to get *locked in*, but rather than seeing this critically it should be seen as a realistic feature of the model, exactly in the spirit of institutionalist pattern modelling.

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[6]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, Allen Turing, etc.

[7]The logical theorist was one of the machines built by Herbert Simon and Allen Newell that were able to proof mathematical theorems and solve logical puzzles *on their own* and in the same manner than humans do.

3.4. Social Structure and Power

The distribution of power in society and its economic, social, and political stratification has always been an important institutionalist research area (Myrdal, 1978, 774). The explicit consideration of network and power structures is already a prerequisite for a model to be holistic and systemic, but as this aspect has been highlighted by institutionalists again and again it will receive particular attention in this article as well.

The study of networks has been a lively area of research and developed an plausible taxonomy for empirical real-world networks and provided several proposals for theories of how these networks could have come into existence. Insitutionalists can build on these insights (and have already done so, e.g. Elsner and Heinrich (2011) AND?) and embed them into a broader theory about the society. But it will be very difficult to build reasonable models including the social network structure without making at least heuristic use of simulations.

Much use of ACE models was motivated by the wish to take the underlying social structure of an economy explicitly into account and not to follow the implicit practice of neoclassical economics to assume complete networks. By the assumption of the representative agent or at least many identical agents, one assumes implicitly a complete network because all agents have to be the same. And the complete network is the only network structure where each agent has exactly the same neighbourhood, namely all other agents. But recent studies of networks have shown that small-world or scale-free networks are much more likely to exist in reality. Small world networks are characterized by small average path lenghts between the nodes and comparatively high degree of clustering. 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 simulations, and even if they cannot provide a complete explication, they are necessary to deal with such abstract structure such as networks. Furthermore, the existence of certain network structures (e.g. particular scale-free networks) were proposed to give rise to self-organised criticality, a concept that should be of interest for institutionalists (see Section 3.1.2, and the identification of scale-free networks (and their role in the models) should therefore be taken into account. Furthermore, Albin and Foley (1992) and Gintis (2007) simulated the distributional effects of changing network structures in the general equilibrium framework and showed how a shift from central to de-central organization has severe distributional effects. Their models remained very abstract and one would not classify them as institutionalist models. They exemplify, however, how big the consequences of a small change in the underlying network structure can be. This insight is important for institutionalists when describing the stratification of real-world economies, because networks probably play an important role for the observed stratification (and unequal distribution of wealth). In order figure out how this role looks like, one must build on simulations of these network structures.

This is especially the case because network structures are a catalysator to other aspects: Page (2012) shows how the presence of heterogeneous agents and an explicit network structure are mutually reinforcing concerning the effect on the modelling outcome. To have these results in mind is important for the construction of purely verbal models as well. We live in a world where economic networks of direct interdependent agents acting without any central control become more and more important. 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. Especially if one tries to build systemic and holistic models. To *explain* rather than just to describe the role of network structures, simulations can be a powerful heuristic. Institutionalist do not really have an alternative to ACE models in this respect, as problems including network strucutures very quickly become intractable in an analytical sense and institutionalists will not be willing to sacrifice enough realism to make the system tractable again. Purely verbal models, on the other hand, are not accurate enough to capture the small but important differences of various network structures.

3.5. Realism and a focus on explanatory power in contrast to simplistic instrumentalism and alleged predictive power

It is not entirely clear whether the practice in neoclassical economics should be described as entirely instrumentalist. But no competing explanation, e.g. economic models as credible worlds (Sugden, 2009), analogies (Gilboa et al., 2014), fairy tales (Rubinstein, 2006) or thought experiments (Mäki, 2005), argues that neoclassical models aim to be realistic. And few economists deny that the majority of neoclassical models put a strong focus on predictive power rather than explanatory power.

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. This is one reason for the strong connection between institutionalist economics and critical realism. ACE models are of course simplified abstractions of real world economies. But strictly speaking they share this property with any model, including the mainly verbal models elaborated by institutionalist economists. But this does not mean they cannot be realistic. This is particularly the case since the programming paradigm called *object oriented programming* (OOP) became the dominant paradigm in ACE.

The idea behind OOP is to build programs by defining objects, which should correspond to some entity in the real world, and methods on these objects, which should correspond to processes in the real world. For example, agents in ACE models are objects.[8] They correspond to something in reality, in the case of ACE most commonly to humans. These objects have certain attributes, e.g. wealth, health or property. A corresponding method manipulates the attributes of the agent, e.g. by specifying how an interaction with an other agent changes the wealth of the agent. Because different

[8]In fact, agents are usually *classes*, which is a certain type of objects.

attributes can be accessed by different methods, the attributes to not have to be expressed in the same unit. This means that one can study multi-dimensional phenomena (with, of course, multi-dimensional results) and is not obliged to express anything in terms of money, utility or any other abstract concept. OOP encourages the modeller to build models that are strongly oriented on reality. This makes the computational model transparent and comprehensible and contrasts with the non-realistic approach of neoclassical economics.

4. Other formal approaches in Institutionalism

Although institionalists have always been very sceptical against any kind of formalization, there were some notable attempts to include more formal analysis into institutionalist theorizing. In this section I will discuss three examples and review their success from an institutionalist point of view.

4.1. The Social Fabric Matrix

The Social Fabric Matrix Approach (SFM-A) was developed by Hayden (1982) and summarized recently in Hayden (2006a). It has been used by institutionalists suggesting that it represents a formalism consistent with OIE methodology (Fullwiler et al., 2009, p. 1). A SFM is a map representing the "relevant set of influences that shape the behaviour of a system" (Gill, 1996, p. 169). It is 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 that system. To facilitate the analysis, Hayden (2006a) gives a set of six important categories, which should be considered by the researchers. The categories include *cultural values*, *social beliefs*, *social institutions*, *personal attitudes*, *technology* and *ecological systems* (Hayden, 2006a, p. 75). The distinction of the six categories does not suggest an independent existence, but is made in a heuristic sense only to facilitate the understanding of the system as a whole. The researcher then has to specify the components of the system and put them into a kind of input-output matrix[9], which then represents the flows among the components. This helps the researcher to identify the deliveries between the components. As it is always true for heuristics, the process of completing the matrix forces the researcher to accumulate knowledge about the system such that the matrix as such is merely used to illustrate the results. The SFM might be seen as an evolving checklist or a topoi for the adequate modelling of a complex system: It forces the researcher to think through the system as a whole, to identify all relevant variables and their relation, and then to formulate a coherent theory.

Useful as it is, it does not create new knowledge in itself. The task of thinking and discovering new insights is left entirely to the researcher - this makes modelling a

[9]The difference to the input-output matrix, in which all rows are filled with monetary values, is that a SFM is not additive, as the rows might include, water, pollution and money, while an input-output matrix uses monetary units only. This shows the wider perspective of the SFMA.

safe exercise, as the matrix cannot be misused like analytical tools. But it might not exhaust all technical opportunities offered to the researcher.

4.2. System Dynamics

System dynamics was originally developed by Forrester (1971) and introduced into institutionalist economics by Radzicki (1988) who considered institutionalist pattern modelling, as outlined by Wilber and Harrison (1978), to lack precision. He hoped to address this shortcomming via system dynamics. Similarly to ACE models, "a system dynamic pattern model is actually a system of highly non-linear differential equations that has no exact analytical solution" (Radzicki, 1988, p. 652).[10] Radzicki argues that the computational modelling technique of system dynamics represents a computational approach broadly consistent with the institutionalist pattern modelling. He argues to combine the two approaches into what he calls "Institutional Dynamics" (Radzicki, 1988, p. 634), in order to facilitate the identification of relevant factors in institutionalist analysis, to increase the transparency and rigor of the verbal pattern models and to simulate the potential effects of policy measures. The fundamental idea was to to create *computerized pattern models* by "translating the perceptions or mental models of a participant-observer into computerized pattern models".

As system dynamics focuses on positive and negative feedback loops, what is the participant-observer's search for themes in the original formulation becomes a structured search for positive and negative causal feedback loops (Radzicki, 1988, p. 638).

A model is built by identifying the important variables (or "stocks") of the system under consideration and the dependency structure among the variables (the "flows"). Particular attention is paid to feedback loops and the determinants of the flows. The latter are then expressed via equations and after specifying the initial conditions for the system, the resulting system of (usually highly non-linear) equations is simulated on a computer. There are no equilibrium assumptions or the like because an unambiguous analytical solution is not attempted for.

The resulting models are able to deal with mutual interdependence of the system components as their states are updated in very small time intervals. One therefore is not obliged to make the dubious *ceteris paribus* assumptions limiting the applicability of e.g. econometrics to the study of more complex systems (as insitutionalists consider the economy to be). Similarly, problems of simultaneity can be addressed intuitively. Because the resulting computer program is able to conduct out-of-equilibrium analysis it seems to be perfectly suited to represent fundamental concepts of institutionalist economics like Myrdals concept *circular cumulative causation* (Myrdal, 1944, 1958). However, as the focus is on the macro properties, one usually assumes homogeneous and static underlying micro entities, a fixed system structure and there is no way to model the decentralised self-organisation and emergence, as there is only one level (the macro level) in the model.

[10] A subtle but important difference is, however, that ACE models are usually expressed via difference equations because they can handle only discrete time steps. This is not important for the present discussion but the issue will be taken up when comparing the two approaches in Section 5.

System dynamics is usually seen as a heuristic; although, in contrast to SFMA, it produces new knowledge via the simulations, that was not present in the researchers mind before running the simulation, its results need to be embedded in a broader institutionalist model. [11]

4.3. Institutional Dynamics and Evolutionary Game Theory

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 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 endogeneously* 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 addresses this shortcomings using an *evolutionary-institutional interpretation of game theory* in the Axelrodian framework of the evolution of cooperation.

Elsner elaborates further complementaries and equivalences between the two approaches and stresses the similar policy prescriptions derived from the two perspectives (Elsner and Heinrich, 2011, p. 38).

He argues that although game theory cannot provide an epistemological bases comparable to that of institutionalism, it can, if embedded into a broader institutionalist process story, add rigour and logical depth into the institutionalist analysis, allows 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 emergence of ceremonial dominance.

[11] The approach came under heavy critique by Hayden (2006b) who argued that it is incapable to capture essential ideas of institutionalist pattern modelling, in particular to address hierarchy, feedback, and openness effectively. He considers the approach to make too strong assumptions regarding the closedness of the system under investigation and to focus on (static) feedback loops, rather than on real dynamics caused by the relations between the system itself, and the surrounding systems related to it. In a reply, Radzicki and Tauheed (2009) argued for inadequacy of Hayden's critique and provide a list of best practice examples proving (in their view) the adequateness of system dynamics for institutionalist analysis. It is not the aim of this paper to go into the discussion about the adequateness of system dynamics and the interested reader is referred to the above cited articles and the reply of Hayden (Hayden, 2009) to Radzicki and Tauheed (2009).

There were other attempts to reconcile institutionalism with (especially evolutionary) game theory before, e.g. Hedoin (2010), Pelligra (2011) and Vilena and Vilena (2004). Many institutionalists still struggle with the application of game theory as it also plays an important role in mainstream economics. This is particularly true for the value sensitivity of game theoretic models that are, at least in their classical interpretation, rooted in an individualistic perception of the human individual.

But the application of game theory is not considered a value in itself and the institutionalist authors manage to provide adequate process stories into which they embed their game theoretic analysis, which, in the end, takes the form of a heuristic adding analytic clarity to the well-known institutionalist concepts. 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. Discussion

5.1. Affinity to the institutionalist approach

Based on Section 3 one can conclude that ACE models may be affine to institutionalist pattern modelling. There are some qualifications to this conclusion, however. Firstly, ACE models 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 should provide strong theoretical underpinnings for the ACE model. Especially, the assumptions made must be justified and the range of applicability of the models must be clarified. The overall insights of a study can never be reduced to the simulation results - only the interpretation of the results in the broader and therefore necessarily verbal discussion yield scientific process. Thus, ACE models are not self-contained. They should be considered to be a heuristic in the overall attempt to address a real-world problem. The formal model has no value in itself and must be judged on its ability to support the researcher to understand aspects of the overall problem that she would otherwise not be able to explain. The assumptions made in order to build the formal model should be interpreted as heuristic assumptions in the sense of Musgrave (1981): They get dropped later in the conclusion of the study and the fundamental relationships one has identified can be expressed in a purely verbal manner.

5.2. Major chances and challenges

This does not mean that ACE models might not be necessary in some instances: If the economy is as complex as it is claimed by institutionalists, ACE as a heuristic can be necessary to study the self-organizing character of the (organized-complex) economy and the resulting emergent properties. As argued above, this is particular true if one considers the social structure of the economy and needs to answer questions of how different network structures influence the overall pattern and dynamics. Although this question might be answered verbally in the end, the sentences could not have been filled with content without having conducted ACE-based simulations before.

I argue that ACE models can help to increase the quality of institutional pattern models especially in the following three respects:

Clarification of the relevant factors. ACE models can help to identify whether a factor is sufficient or necessary to produce a certain pattern. In sharp contrast to the *ceteris paribus* analysis in neoclassical economics, it is well suited to study the dynamic interaction effects of several factors and the role of networks as a catalysator for other factors as discussed in Section 3.4. Such interaction effects are also very difficult to identify in purely verbal models. Furthermore, ACE models 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.* Equifinality is very important to identify because in order to explain an observed phenomenon in an open system, it might be insufficient to provide one universal explanation. This is what neoclassical economists do when they require everything to be explained in terms of the utility maximizing behaviour of some representative agents. But in open systems, the same phenomenon can be reached via very different ways and from very different initial conditions. It is therefore very important to provide a *constructive* explanation of a phenomenon, i.e. to show exactly how the presence of some relevant factors 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 simulation studies, but frequently absent in the abstract (often non-constructive) mathematical models of neoclassical economics.

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 pay much attention to realist models and therefore favour accuracy above generality.

There are, of course, some exceptional, more general theories developed by great instutitional minds such as Gunnar Myrdal (circular cumulative causation, backwash and spread effects), Clarence Ayres (the nature of technology and skills), and Thorstein Veblen (e.g. conspicious consumption, institutional life cycle), among others.

Although Diesing (1971, p. 198) considers these concepts to be a mere grouping of real cases (using the term *real type*), I think they are better seen as mechanisms taking place in many real world situations. To identify such mechanisms is of particular scientific value and ACE models may facilitate their exploration by helping to construct and to test models with a medium range of abstraction.

Improving contextual validation Insitutionalists should formulate hypothesis about the system under investigation and evaluate the hypothesis via *contextual validation* (Wilber and Harrison, 1978, p. 76). This involves " comparing it with other kinds of evidence on the same point" or by "evaluating the source of the evidence by locating other kinds of evidence about that source."

Unfortunately, contextual validation lacks the rigour of more formal models and can only indicate varying degrees of plausibility (Wilber and Harrison, 1978, p. 76). This plausibility can be increased via the application of ACE models that can explicitly show constructively how the proposed mechanisms yield a pattern observed in reality. By doing so, they help to consider the openness and equifinality of real world economic systems (see above). They do so not only by validating the resulting pattern, but also the whole adjustment process leading to the pattern and therefore allow a much more detailed examination of the hypothesis than mere statistical hypothesis testing.

The question of how to implement empirical studies has always been lively discussed by institutionalists. Wesley Mitchell at the latest has put the issue on the insitutionalist agenda (Hirsch, 1994). His (constructive) critique that the veblen-ian kind of investigation is too less data-driven and too speculative has has always been controversial, especially because of the (legitimate) critique of the praxis in econometrics. ACE models can be a valuable tool to confront institutionalist theories with the data. But unlike most other statistical methods, it is accesible to a wide range of verification techniques. Especially the fact that ACE models can be evaluated on different scales (microcalibration, macrocalibration,...) restricts their use for curve-fitting so common in many econometric studies. ACE models can be tested much more transparently that econometric models and they can help to compare insitutionalist models much more concisely with observed data than a verbal analysis can, but more transparently and appropriately than a purely econometric analysis.

Multidimensional models Another advantage of ACE models is that the state of each agent is not necessarily expressed in one dimension only. Because every agent can have several attributes, ACE models are able to provide a *multidimensional* perspective on economic phenomena. While neoclassical economics tend to express everything in "utility" or "income", much less effort was put into the development of multidimensional models. As argued above and shown in the appendix, the attributes of agents can include inconvertible properties such as "literacy" and "income". This makes ACE models particularly useful for the development and testing of multidimensional theories, which have been advocated by institutionalist ever since (Myrdal, 1958) and are considered to be more and more important to tackle the most important challenges of our time (Nussbaum and Sen, 1993; Sen, 1999; Stiglitz et al., 2010).

Increased transparency Although recent incidents such as the misleading study of Reinhart and Rogoff (2010)[12] make it difficult to argue for the superior transparency of formal models over verbal description, ACE models allow in principle an extremely

[12] Based on econometric "evidence", Reinhart and Rogoff (2010) argued that a country with a gross external debt rate above 60 percent of its GDP will experience a decline of annual growth by two per cent, with even worse consequences for higher debt rates. Herndon et al. (2014) showed that the conclusions was a consequence of bad data management and does not hold if the data is used correctly. The original paper played a major role in discussions about austerity policies, especially in the European Union.

rigorous test of their validity: Because the researcher has to write every single assumption into the computer code, a reviewer can reconstruct any train of thought. The ideal case would be of course to publish the code after the publication of the model such that everybody can check how the results depend on the assumptions and a replicability of the study is simplified enormously. 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 Increased transparency is strongly related to the ability to simulate potential effects of policy. Insitutionalists have always seen the necessity for an informed and active role of public policy. Simulations can guide the decision making process for policy makers, as, contrary to neoclassical models, they may not only provide analogies which have then to be interpreted in the public discourse and therefore be instrumentalized easily by opinion leaders, but provide concrete simulation results which are subject to replicability and critical scrutiny by all parties involved. In this respect, they can be discussed in an easier way than mere verbal descriptions and can enhance the ability of insitutionalists to provide reasonable policy advice on a transparent base.

Another important advantage in this context is the constructive character of ACE models: The simulation not only provides results, it also shows how the results emerge. In a dynamic economy, it is important to take adjustment paths into account. And while many purely formal models are not capable to describe the exact adjustment paths (e.g. game theoretic models hinting to an existing Nash equilibrium), ACE models can show the effects on all involved agents on all points of time. ACE models truly *generate* their results step by step in a transparent manner (Epstein and Axtell, 1996).

But there are of course also possible pitfalls of applying ACE models in an institutionalist framework. These are in particular the following:

Instrumental tendencies ACE models 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 what is going on in reality, i.e. do forecasting a la Friedman (1966). I have argued earlier that the OOP programming paradigm facilitates a realistic design of ACE models. But if one manages to replicate an empirical pattern very accurately with an ACE model of which one knows that certain processes do not reflect known facts adequately it takes much effort to discard or modify this model. But this is what institutionalist ACE modellers have to do.

Implicit focus on predictive power Related to this difficulty, ACE models 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 ACE model one might be tempted to let the model run 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 higher level of explanatory in-accuracy. Such an approach is difficult to be identified later on and requires an intensive review of the ACE model.

Overerparametrization and decreased transparency This relates to another problem, namely that ACE models tend to be overparametrized. This means on adds 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 to extremely complicated models that are very hard to review and very hard to discuss. Contrary to the fact that good ACE models can help to identify important factors and to increase the transparency of a study, bad ACE models do the reverse. And the distinction among the two classes is not always straightforward. The problem of overparametrization of ACE models is well known in the community 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. Especially insitutionalists not yet very proficient with ACE modelling must rely on the judgements of others. But in defense of ACE models one must mention that other quantitative models, but verbal models as well, 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 a danger as well, e.g. if does not take dynamic interaction effects into account.

All arguments considered it seems safe to say that ACE models are consistent with insitutional pattern modelling and that they can prove to be extremely valuable for institutionalist pattern modelling. There are, however, some potential drawbacks and as ACE models are also used in scientific frameworks incompatible with pattern modelling, every single model must be judged on its own right.

5.3. Relation to former formalizations

After discussing the consistence of ACE models with institutionalist pattern modelling, I briefly clarify the relation to other attempts of formalizing institutionalist analysis.

ACE models represent a different perspective on the economy than system dynamics and it is therefore difficult to compare the two approaches. System dynamics focus on the aggregate properties of the system and might be seen as a typical macro analysis. It entails stronger assumptions than ACE models and is not able to offer an analysis of how the micro, meso and macro levels depend on each other and how the overall dynamics result from the interaction of heterogeneous agents. System dynamics is therefore not suited to study concepts such as reconsitutive downward causation, self-organized criticality and the requirements for certain institutions to persist in a population of many heterogeneous individuals. Non-trivial aggregation problems might fall outside the applicability of system dynamics because they usually include only one level in the economy. ACE models on the other hand, are predestined for such an investigation. System dynamics have other advantages, especially that they are easier to develop and able handle continuous time. Their heuristic value can be superior to that of ACE models if one is interested only in relation between macro variables. But in situations in which one seeks to study the aggregative behaviour of heterogeneous, boundedly rational and socially embedded agents, one cannot but rely on ACE modelling rather than system dynamics. So the realms of applicability of the two approaches are different.

This is not necessarily true for the SFMA approach. It is not difficult to imagine a study including both a SFM and an ACE model to clarify certain relations and processes in the system under investigation. As both tools are useful to guide the researchers thinking and to get insights, there is no reason to see them as substitutes. Practically, the SFM is more general and less concrete than an ACE model, and might serve as a guide from the beginning to the end of the study. ACE models are more specific and can be used to clarify relationships that are then summarized in the SFM. So the realm of applicability of the SFMA is broader than that of ACE and it might well be that while trying to complete the SFM the researches discovers questions that she is only able to answer through the support of ACE models.

The research program of introducing an evolutionary-institutional interpretation of game theory into institutionalist analysis is similar to that of introducing ACE models. In fact, ACE models are sometimes used to simulate problems formulated in an (evolutionary) game theoretic framework. Especially if one considers complex game theoretic models, analytical solutions might be impossible to obtain. The systems of perpetuous novelty of behaviour studied by Lindgren (1992) are one such example. ACE models are an important tool to study problems formulated in game theoretic language and there will continue to be a lot of synergy between evolutionary game theory and ACE modelling.

Summarizing, while providing a different perspective than system dynamics, ACE models are consistent with the SFMA and often used to study game theoretic models, especially in the institutional-evolutionary approach to game theory. Much is to be gained from an increased collaboration among scholars coming from the different, but complementary fields.

6. Conclusion

I have argued that ACE models can be a valuable heuristic and analytical tool for institutionalist research and its application is affine to the institutionalist **epistemology?** of pattern modelling. Furthermore, ACE modelling represents a more comprehensive perspective than system dynamics in that it tries to investigate the economy "from the bottom up" (Epstein and Axtell, 1996). Because of its agent-based nature it can be used to formalize institutionalist concepts such as circular cumulative causation, reconstitutive downward effects, the emergence and the life cycle of institutions and to increase the understanding gained from these concepts. It is consistent with the SFMA and important for modelling in an institutionalist framework of evolutionary game theory.

This article suggested institutionalists to be open-minded to the application of ACE models as it entails a large potential to clarify important and yet unresolved questions. This is particular true for phenomena such as networks, aggregation (and scaling) behaviour and the consequences of policy measures.

In all, ACE models can serve as a powerful heuristic. Similarly to the SFM, it can also be considered to be a *topoi*, i.e. a concept making the researcher ask important questions about the subject of investigation. Because ACE models are difficult to build and one has to state one's assumptions and considerations in an explicit way during the modelling process, even the process of building a model may already enhance the quality of the study.

Further research may use ACE models in practical applications of institutionalist analysis to investigate further its applicability in the institutionalist research program. There are already institutionalist studies based on ACE models, e.g. Hodgson and Knudsen (2004), Elsner and Heinrich (2011), Wäckerle (2014), Rengs and Wäckerle (2014), but as insitutionalist researchers become less sceptical against the method, there will emerge a huge number of questions to be addressed via ACE models embedded in an institutionalist framework. The attempt to elaborate on more general concepts from case studies and to further investigate the role of certain network structures for the social stratification are only two examples for starting points.

Further research should also address whether the application of ACE models is consistent with critical realism, which has been becoming more popular as a philosophical basis for institutionalist modelling and tends to be even more sceptical against 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.

A. Formal Foundations of ACE Modelling

In this short appendix I quickly review the technical underpinnings of ACE modelling.

In a model with N agents, the state of each agent is represented by the variables $x_1, ..., x_n = \boldsymbol{x}$. For every one of the N agents there is one variable representing its state. The set of possible states for every $x_j \in \boldsymbol{x}$ is given by X_j. Generally, agents in ACE models consist of the same class, therefore $X_j = X_k \forall j, k \in N$.[13] That agents are modelled as a class means that they have several attributes. The attributes can include many different, non-convertible properties: One attribute can be the level of literacy of the agent, another attribute can be her wealth and a third attribute can describe her relationship status. The overall state of an agent can nevertheless be represented

[13]Heterogeneity is taken into account by allowing $x_j \neq x_k \forall j, k \in \boldsymbol{x}$.

with a state vector. The overall state space of the system therefore is given by

$$X \equiv X_1 \times X_2 \times X_3 \times ... \times X_n \text{ and } X \subseteq \mathbb{R}^n.$$

How the states of the individual agents change is specified by the local update functions $\mathcal{F} = \{f_1, ..., f_n\}$ with

$$f_i : X_i \rightarrow X_i, \quad \forall i \in N.$$

The inputs of the function f_i are the state of the agent i and all the other agents in the neighbourhood of i, $Z_0(i)$.

The neighbourhood results from the topological structure of the model which is naturally expressed via a *dependency graph* $Y(V, E)$ in which the number of vertices in Y corresponds to the number of agents. For two arbitrary vertices $i, j \in V : \exists \langle i, j \rangle \in E$ iff f_i depends *inter alia* on x_j.[14] For simplicity define the neighbourhood of agent i as $Z_0(i)$ including the vertices that are adjacent to vertex i. The input of f_i is then $Z_0(i) \cup \{i\}$. In the simplest case, the dependency relation is fixed, but there are also natural extensions to cases in which the dependence relations are subject to change.

The global dynamics of the model result from the composition of local update functions:

$$\Phi = (f_1, ..., f_n) : X^n \rightarrow X^n.$$

It is specified by $\Phi(\mathcal{F}, Y, \pi)$ as the composition of the local update functions according to a given update schedule π and a given dependency graph Y.

For the case of synchronous updating (and thus a *parallel dynamical system*), the resulting system is:

$$\Phi(x_1, ..., x_n) = (f_1(x_1, ..., x_n), ..., f_n(x_1, ..., x_n)),$$

while the sequential case (*sequential dynamical system* with update order $\pi = (\pi_1, ..., \pi_t)$ is given by:[15]

$$\Phi_\pi = f_{\pi_t} \circ f_{\pi_{n-1}} \circ ... \circ f_{\pi_1}.$$

While ACE models can involve continuous functions as well, e.g. in the decision making process of the agents or for the specification of the update functions, the update mechanism for the agents is discrete. The overall dynamical system is therefore discrete by nature, but can involve continuous processes.

[14] If the dependency of agents is defined symmetrically, i.e. x_i depends on x_j if and only if x_j depends on x_i, then $Y(V, E)$ is an undirected graph and $\langle i, j \rangle = \langle j, i \rangle$.

[15] In the economics literature the mathematical study of ACE models is less well known but there is a huge literature studying the conditions necessary for the existence of fixed points, reachability problems (Barrett et al., 2003) and predecessor existence problems (Barrett et al., 2007). Although it was shown that these problems are very complex and not solvable for the more interesting systems (Barrett et al., 2006), there are valuable results about how to express the *equivalence* between different models (Barrett et al. (2001), Laubenbacher and Pareigis (2001), Laubenbacher et al. (2009), Reidys (2005)) and about the mathematical *category* of such systems (Laubenbacher et al., 2009).

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