A Cognitive Approach to Modelling Structural Change

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Introduction

The ability to account for developing as well as stable states is considered an important general requirement for theories in a variety of disciplines. Sometimes, however, theories developed in the first instance to deal with the more straightforward cases do not easily extend to the more difficult cases. This is apparent not only in Economics, where rapidly changing structures call for the re-consideration of established forms of representation, but also, for instance, in Cognitive Psychology where a range of abilities are modelled prior to consideration of how they are learned. The underlying rationale may be the idea that, given an understanding of the simpler issues, we will be in a better position to tackle the more complex ones. However, this is a hope which does not seem to have a sound basis; whereas it is reasonable to assume the converse, that theories which incorporate development will be sufficiently general to deal with stable states.

Constraints on Theories

A problem confronting theories of development is that of how they are to be reasonably constrained. Theories concerned with stable states are normally constrained by the empirical data. For instance, in Economics, if a set of stable relationships are proposed to exist amongst a number of variables, then empirical data can be used to confirm or disconfirm these or delineate the conditions under which they hold. Similarly, in Linguistics, theories of grammatical representation are found to be inadequate if there are constructions in some known natural language which they cannot represent. They cannot actually be disproved if they license a range of constructions which aren't observed, because we do not have access to all possible languages: but this is also taken to be a basis for criticism. In relation to theories of development, similar kinds of data are available, but they are much less straightforwardly applied, especially in constraining the theories which are proposed in the first instance. It is suggested here that, for this purpose, we need to consider what other kinds of constraints are available.

A common property of constraints is that they are things that are known. Thus the proposal of theories can be constrained by any relevant knowledge to which we have access. This sounds obvious, but, due to factors such as disciplinary divides, theory development does not always take into account all the information available. For example, in Psychology, a variety of child grammars have been proposed on the basis of the language children are observed to produce. A typical problem with these is that they do not provide a suitable basis for development of the kinds of representations used to characterise adults' grammatical competence, because the formal constraints of Linguistics have not been taken into account. In the case of Economics and other Social Sciences, it will be argued, important constraints on theories and invariant features within models can be provided by the Cognitive Sciences.

Social and Cognitive Sciences

The Social Sciences recognise that there are phenomena which can be observed at the level of the group which are distinct from those observable at the level of individuals. The features of individual members cannot reliably be used to deduce the features of the social system. Similarly, the features of the individual cannot be deduced from those of the group. However, there is an important relationship of dependency, insofar as the social system cannot exist in the absence of the individuals which constitute it. We know that social systems emerge through the interactions amongst individuals, and the Cognitive Sciences provide us with a substantial body of knowledge concerning the kinds of beliefs, goals, and capabilities which characterise individuals. On this basis it is proposed that economies and other social systems can be modelled in terms of the interactions amongst cognitive agents. These can be viewed as providing local constraints which complement the global constraints on models deriving from the observed behaviour of the social system as a whole.

The cognitive approach is inherently suitable for modelling structural change. This is because, at the level of the cognitive agent, there are characteristics which persist in changing as well as stable environments. Thus recourse to a lower level of representation gives us the kind of general applicability to social systems which we require.

Characteristics of Cognitive Agents

While there is considerable variation amongst individuals, there are also important shared characteristics underlying behaviour which can be incorporated into models of interacting cognitive agents. Individuals have goals, beliefs (including meta-beliefs about the beliefs of agents), and capabilities, and these can change through social interaction with other agents. While goals, knowledge, and beliefs will be to a certain extent context-dependent and thus specific to particular models, there are features of human reasoning which are not domain-specific. Which of those aspects of human reasoning are relevant will depend on the context. Thus not all models will be required to capture the characteristics of, for instance, humans' decision- making processes. Some of the more general characteristics of human reasoning are outlined here and related to the issue of modelling structural change.

The idea that humans are rational has come to be recognised as an idealization which has been replaced by the idea that they are boundedly rational. The boundedness of rationality derives partly from the limitations on the information available to and processable by the individual located in space and time. These mean that, in reasoning, we tend to use information that is local (in time as well as space) rather than global and we don't carry out an exhaustive search of the possibilities. Additionally, there are biases inherent in our reasoning. We are not on the whole good at, or tend not to use, logical deduction as a basis for reasoning. What we are good at is pattern-matching, or induction. There are some obvious advantages to this over logical deduction. Induction enables us to overcome the limitation of being unable to take into account an exhaustive amount of information: familiar patterns can be used as a basis for focusing on that information which is likely to be most useful to us. Pattern-matching is also flexible which has the advantage that it enables us to deal with situations which are similar to, rather than identical with, those previously encountered. A problem with induction, however, is that, unlike deduction, it is logically invalid. This means that, for instance, what is normally an appropriate response to a particular situation is not necessarily always an appropriate response. Additionally, flexibility in pattern-matching may serve to magnify the unreliability of induction, since truly novel situations may be inappropriately conceptualised in terms of familiar patterns.

Cognitive agents' behaviour is determined jointly by their characteristics and their situation within the social system; that is, by a local perspective on their environment. This means that they are a particularly suitable form of representation for modelling situations, like those involving structural change, where a set of global relationships characterising the social system cannot be presupposed.

Organizational Change

At the Centre for Policy Modelling we are currently working on representing organizations for the purposes of modelling organizational change. Previous work in computational organizational theory has modelled the effectiveness of different organizational structures and task decomposition schemes. However, it has not investigated the effects of the actual processes involved in a change such as downsizing. We represent organizations in terms of interacting cognitive agents, as outlined above. We hypothesise that the behaviour of individuals is influenced by their beliefs and goals (which may conflict with organizational goals). These may be changed as a result of organizational changes, and the resulting changes in behaviour may in turn impact upon the organization, and so on. While it is not easy to reason about the effects of such complex interactions, computational models enable us to simulate them.

We represent the development of experience with individual activities as a search by an "activity agent" over an infinite network. The network is infinite in the sense that more nodes and arcs are created before the existing node and arc sets have been exhausted. In addition, the activity agents learn about other agents. In effect, they develop models of the effectiveness and reliability of the other agents in the organization. We have not found a means of modelling any process of spontaneous generation of organizational structure. It seems inefficient to ask agents to come together and then learn to cooperate with each other. Even randomly generated cooperative agreements and the resulting organizational structures are difficult to develop. Certainly, that process of organizational development is far more difficult to model than a process whereby an initial structure of cooperation is imposed on the organization and then modified in the light of the experience of agents with one another.

The conclusion is similar to that reported in another paper contributed to this workshop: the model of emergent markets in the Russian and Belarussian economies described by Moss in "Declarative Modelling of Structural Change". It is easiest to model learning and purposive change initiated by agents whose behaviour collectively determines the characteristics of their environments if they start from a known initial structure and modify their behaviour in light of their own experience and with limited computational and information processing capacities. This process, described clearly by Penrose (1959) and Chandler (e.g. 1962) on the basis of business histories and case studies, is very different from the genetic algorithm models and models based on constrained optimization over finite information and strategy sets. It is much closer to historical studies and the lessons from cognitive science than it is to economics.

Summary

For modelling structural change in economies or other social systems we need theories that are both general and constrained by information of a local kind. We can meet these requirements by representing social systems in terms of the interactions amongst the cognitive agents which constitute them. We do not seek to reduce social phenomena to individual behaviour; rather, we view them as emergent from and dependent upon the properties of individual behaviour and social interaction.