

Rerum cognoscere causas:
**Part II - Opportunities generated by the agency/structure debate
and suggestions for clarifying the social theoretic position of
system dynamics**

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This is the second half of a two-part paper dealing with the social theoretic assumptions underlying system dynamics. It was concluded in the first half that analysing system dynamics using traditional, paradigm-based social theories is highly problematic. An innovative and potentially fruitful resolution is now proposed to these problems.

In the first section it is argued that in order to find an appropriate social theoretic home for system dynamics it is necessary to look to a key exchange in contemporary social science: the agency/structure debate. This debate aims to move beyond both the theories based only on the actions of individual human agents, and those theories which emphasise only structural constraints. Emerging from this debate are various theories which instead aim to unite the human agent view of the social realm with views which concentrate solely on system structure. It is argued that system dynamics is best viewed as being implicitly grounded in such theories.

The main conclusion is therefore that system dynamics can contribute to an important part of social thinking by providing a formal approach for explicating social mechanisms. This conclusion is of general significance for system dynamics. However, the over-arching aim of the two-part paper is increase understanding of system dynamics in related disciplines. Four suggestions are therefore offered for how the system dynamics method might be extended further into the social sciences. Presented in the right way, the formal yet contingent feedback causality thinking of system dynamics should diffuse widely in the social sciences and continue to make a distinctive and powerful contribution to them.

"Felix qui potuit rerum cognoscere causas"

"Happy is he who comes to know the causes of things"
Virgil - *Georgics*, Book II, line 490. 29 BCE

Recapitulation - the structure and aims of this paper

This is the second half of a two-part paper dealing with the social theoretic assumptions of system dynamics. Two issues were considered in Part I. Firstly, the implicit but underlying social theory of the field was probed. This was done by relating the range of system dynamics practice to a framework - widely used in both OR and systems science - which organises the assumptions behind traditional social theoretic paradigms (Burrell and Morgan, 1979). The aim was to answer the question: How do the ideas of system dynamics relate to traditional

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social theory?¹ Distinct and surprisingly varied groupings of practice were identified, making it difficult to relate system dynamics to any one paradigm with any certainty. The difficulties of establishing a social theoretic home for system dynamics were then exemplified by considering a second issue, crystallised by the question: Is system dynamics deterministic? It was shown that system dynamics simply did not fit well with either pole of a dichotomous voluntarism/determinism axis. Part I therefore concluded that definitively placing system dynamics with respect to traditional social theories is highly problematic. In this present Part II a resolution is offered to these problems.

The first main section considers some recent social theories which seek to integrate the 'agency' and 'structure' paradigms that have traditionally been employed in social theory. Hence, the third issue discussed across the two parts of this paper is whether system dynamics relates best to those theories which seek to integrate views based on the actions of individual human agents with those views which emphasise structural constraints. The question being considered is: The agency/structure debate - opportunity for system dynamics? A description is given of these theories and what was formerly proposed as "a bold conjecture" (Lane, 1999b, p. 521) is advanced here as a firm thesis: that the implicit social theory of system dynamics is consistent with such integrative theories.

Across its two parts, the over-arching aim of this paper is to use social theory to enable system dynamics to be extended further into the social sciences. The second main section therefore draws on all of the previous analysis to make four suggestions for clarifying and innovating the social theory of system dynamics in ways which improve communication between system dynamicists and mainstream social scientists. A conclusion section closes the paper.

The agency/structure debate - opportunity for system dynamics?

This section draws on two previous findings. Firstly, that system dynamics is difficult to place in terms of traditional social theories. Secondly, that system dynamics challenges the dichotomy of the determinism/voluntarism debate. The second point begins to explain the first: if system dynamics does have a social theoretic home then it must be different from the traditional ones considered so far.

Such a home may be found in those theories emerging from the 'agency/structure debate', one of the most important innovations in social theory (Layder, 1994; Ritzer, 1996). The first two sub-sections outline theories which have emerged from this debate. In the subsequent sub-sections, it is first suggested that system dynamics would fit naturally with such theories. Then the difficulties and opportunities of achieving that fit are considered.

The Integration of Agency and Structure

The tradition of Comte has sought to explain how objectively describable structures constrain human action. This contrasts with the tradition of Hegel, Husserl and Schutz which has sought to explain how individuals act as voluntaristic human agents, continually creating the social world by ascribing subjective meaning to their actions. These views - 'structure' and 'agency' - are not dichotomous but co-existing. The traditional distinction made between these 'objective' and 'subjective' approaches is increasingly seen as describing extremes of a dialectical activity. The means by which the two can be integrated is at the heart of the 'agency and structure debate' in social theory (Layder, 1994; Ritzer, 1996)².

The insight that there is such a dialectical relationship is not new. Durkheim, later Marx and Parsons may have concentrated on understanding the objective, factual nature with which the social world presented itself. However, in different ways they acknowledged the dualistic

nature of agency and structure, even though they ultimately gave priority to the latter. Weber's integrative view shows much more clearly since he attempted to bring subjective understanding within his analysis of structure.

This background aside, social theories explicitly built on the idea of integration are an innovation. A seminal post-war attempt to unite agency and structure is the 'Social Construction of Reality' thesis (Berger and Luckmann, 1966 p.18). These authors propose that "Social order is ... an ongoing human production" (p.52)". They describe a cycle of activities which form this production. Social structure manifests itself via the fact that "Institutions ... control human conduct by setting up predefined patterns of conduct, which channel in one direction as against the many other directions that would theoretically be possible" (p.55). This takes place because individuals apprehend the world using certain values and roles, the internalised form of the above channelling. When humans act they externalise their subjective interpretations of the world and in doing so they re-vivify the patterns of conduct, or 'typificatory schemes'. Over time these therefore take on objective characteristics. As a result, "The reality of everyday life contains typificatory schemes in terms of which others are apprehended and 'dealt with' in face-to-face encounters" (p.30-1) and so the cycle continues.

This book is one of the most influential modern forms of the dualistic approach. Today, social thinkers offer a number of innovative theories which attempt to synthesise agent-based and structure-based approaches in different ways. Bourdieu's 'constructivist structuralism' links *Habitus* and *Field* (Bourdieu, 1977). Habermas' 'theory of communicative action' deals with the interaction between the *Lebenswelt* and the (social) system (Habermas, 1981). Luhmann's autopoietic systems theory addresses individual consciousness ('psychic systems') and processes of communication (his social system) (Luhmann, 1984). Finally, Archer's morphogenetic systems theory explores the link between agency and culture (Archer, 1988). To exemplify these ideas, attention now turns to the work of Giddens.

Example of an integrative approach: Giddens' Structuration Theory'

Giddens' contribution to dissolving the agency/structure dualism is 'structuration theory' (Giddens, 1976; 1984). This integrative theory is, "a hermeneutically informed social theory ... [which] recognise[s] the need for connecting an adequate account of meaningful 'action' ... with the analysis of its unanticipated conditions and unintended consequence" (Giddens, 1982, p.7).

In structuration theory, human agency and social structure exist in a reflexive - one might say feedback - relationship to each other; "The structural properties of social systems are both medium and outcome of the practices they recursively organize" (Giddens, 1984, p.25), and, "The day-to-day activity of social actors draws upon and reproduces structural features of wider social systems" (*ibid.*, p.24). This 'dual nature' is central to structuration theory (see Fig. 1).

Structure is the term used to describe the rules that shape social actions and the resources that furnish agents with the power that makes it possible (to varying extents) for them to act. For Giddens, structure is not a static, objective entity; "structure is what gives form and shape to social life, but it is not *itself* that form and shape ... structure only exists in and through the activities of human agents" (Giddens, 1989, p.256). Structure influences actions because it manifests itself via opportunities and limitations for agents. The traditional view of structure is therefore extended to emphasise power and the associated idea that agents are not just constrained by their circumstances but also enabled by them to take certain actions.

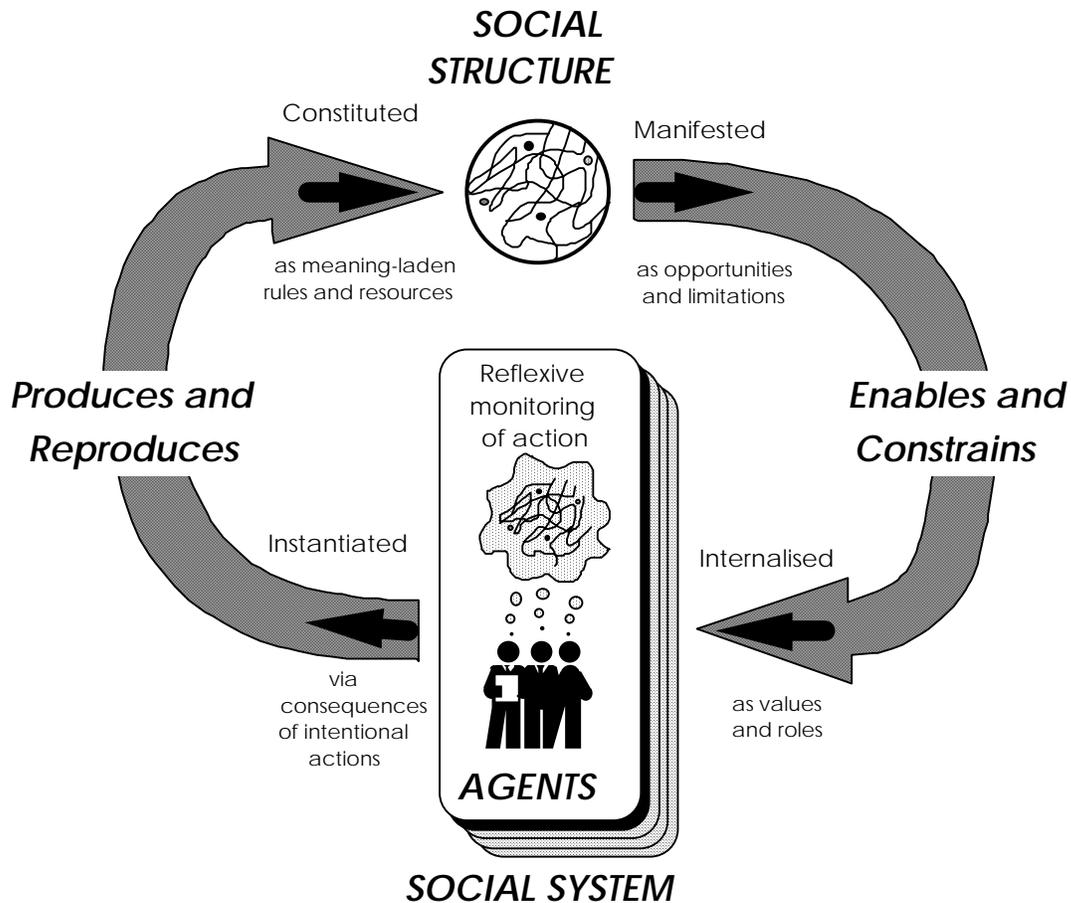


Fig. 1. Representation of the dualistic, or feedback, relationship between agency and social structure described in Giddens' Structuration Theory.

The social system is the observable patterns of interaction and sedimented practices which shape the relationships between agents. An interpretivistic view is adopted to describe how agents internalise the influences of structure. Meaning is attributed to the values and roles that are seen to be contained in the enabling or constraining effects of structure. Agents reflexively monitor such thoughts and interpretations, knowingly applying maxims of behaviour with which they develop routines which make them feel secure and help them to deal effectively with the world. This monitoring is externalised - or 'instantiated' - via intentional social actions.

The existence of such meaningful acts has the property of reproducing current aspects of structure and producing new ones. A significant element here is that reflexive monitoring can nevertheless result in intentional actions which have unintended consequences. The outcome of creative human acts is therefore meaning-laden rules and resources. The cycle is completed when it is noted that, "In reproducing structural properties ... agents also reproduce the conditions that make such action possible" (Giddens, 1984, p.26).

Structuration theory involves a rejection of grand theories and Humean accounts of causal laws (Giddens, 1976; 1984). In social science, he argues, it is reasons that are causes and reasons are rationalizations of action. However, this rejection of 'event causality' (Giddens,

1976) does not strand the social researcher with subjective interpretation - *Verstehen* - as the only mode of explanation. Indeed, Giddens pronounces unacceptable, "the hermeneutical notion that causal laws have no place in social sciences at all" (Giddens, 1982, p.15). Structuration theory posits a notion of 'agent causality' in which causal relations are an element of the rationalizations and maxims that agents use. Giddens describes, "an agent's reflexive monitoring of his or her intentions in relation to both wants and appreciation of the demands of the 'outer' world" (Giddens, 1976, p.91). Agents take actions because mental processes lead them to expect certain consequences. However, such causal monitoring does not constitute a general law. Giddens is only willing to admit to 'generalizations' which, "are intrinsically 'historical' in character: they [only hold] given specific conditions of 'boundedness' of knowledgeably reproduced systems of social interaction" (Giddens, 1982, p.15). Such causal generalizations will be true in very specific circumstances only and are altered by intentional action. In explanation, Giddens invokes the concept of the 'double hermeneutic', the term for the effect by which social research can lead to knowledge which alters the maxims of intentional agents (Giddens, 1976). Structuration theory therefore indicates not only the appropriate location of causal knowledge but how that knowledge reflexively re-enters the cyclic relationship between agency and structure.

Agency/structure integrative theories : a natural fit for system dynamics?

Giddens' work and any of the theories cited above are certainly not in complete harmony. In now considering the opportunities afforded to system dynamics by engaging with agency/structure theories it is therefore vital to note that any such engagement will be variegated, with specific theoretical and empirical tasks being required. The links that these theories have with system dynamics was first identified in Lane (1999b) but the greater depth of treatment in this paper makes it possible to explore this link in more detail. There is a *prima facie* case that system dynamics and these integrative theories have much in common. Such links extend down below the surface, however. Taking the example of structuration theory, a more detailed comparison can be made - though the main themes of the argument will apply more widely.

In structuration theory, social structure can be seen to be providing resources that are drawn on to enable action, or limitations which constrain action; in system dynamics terms, the resources can be thought of as stocks of roles or values, these stocks acting as limiting capacities by standing as the goals of negative feedback loops. In structuration theory, such resources bound human agency; this is what system dynamicists refer to as partial structural control of human behaviour. In structuration theory agents monitor their environment and use maxims to guide their actions; in system dynamics terms, this monitoring is the collection of information feedback, whilst it is mental models that influence actions. In structuration theory these actions reproduce resources or produce new ones; in system dynamics terms, such reproduction is the accumulation of a flow into a stock. Finally, in structuration theory, as the loop of activities is conducted, actors' knowledge about the world changes; to system dynamicists this feels like the updating of mental models, or learning.

So the separate elements offer a natural fit and to system dynamicists this seems to be a very reasonable way to look at the world. There is also fit at the level of the systemic properties. For example, Giddens places considerable importance on the ideas that maxims do not necessarily lead to the intended consequences, indeed, "the further removed the consequences of an act, the less likely those consequences are to be intentional - but this is, of course, influenced both by the scope of the knowledgeability that actors have" (Giddens, 1984, p.11). This feels like a combination of the effects of bounded rationality, delays, accumulation/draining processes and non-linearities, brought together in multiple feedback

loops and producing counter-intuitive behaviour. What is more, the field seems to be able to answer some of the questions that structuration theory poses. Question from Giddens: "How ... does it happen that cycles of unintended consequences feed back to promote social reproduction across long periods of time?" (Giddens, 1984, p.14). Answer from system dynamics: limitations in memory and cognitive skills mean that when agents attempt to infer the dynamics of mental models involving feedback, they fail to work out the consequences of their assumptions in a complete and logical way; furthermore there are a host of reasons why it is hard to learn that this is happening and put this situation right without formal modelling.

This should not be surprising. The feedback nature of past social theories has been observed (Richardson, 1991), 'Interactive SD' has been moving in an integrative direction and 'Holon Dynamics' displays some awareness of the range of subjective approaches available in social science. A social constructivist approach similar to that seen in 'soft' OR has been proposed (Lane, 1992; 1994), as has a grounding within Berger and Luckmann's theory (Vennix, 1996; Lane, 1999a) and even out-and-out interpretivism (Lane and Oliva, 1998). The link to integrative theories is arguably a consummation of these developments and is further supported by the more specific proposal that structuration theory can assist in organizational learning (Senge, 1998).

Difficulties and opportunities

The task suggested in this section will not be an easy one but it could be rewarding. The difficulties and benefits are described below.

A DIFFICULT TASK. Any attempt to ground system dynamics in integrative social theories will encounter at least two significant difficulties. The first concerns the nature of some of the social science literature. Social theory can suffer from abstruseness of style and imprecision of terms. In this entire section, not a single one of the social theory references cited contains an equation, or even a 'model' worthy of the name. Trawling sources of this nature with a view to extracting ideas for modelling will be difficult.

The second, related problem concerns the nature of the causal 'laws' that underlie system dynamics. These do not particularly feel like mere hermeneutical generalisations(!) As described in the section on determinism, there is certainly a high degree of contingency in the model assumptions, for example, "The policies are laws of human behaviour, for the circumstances within the model" (Forrester, 1980, p.16-7). The question really centres on the relevance of the representation scheme being used, on the individual causal links put into a model and on the relevance of the rigorous logical deduction offered by computer simulation. What is at stake here is the source of the causal laws that constitute a model. How well does system dynamics fit with the idea of 'agent causality' and the notion that causal laws exist only in that they lead agents to expect certain consequences? Can the field really accept that causal reasoning matters only because a decision maker believes it to be so? These hard questions must be addressed, although some relief may be found in the observation that, "Generalizations about human social conduct ... may directly reflect maxims of action which are knowingly applied by agents ... just how far this is the case in any specific set of circumstances has to be one of the main tasks of social research to investigate" (Giddens, 1984, p.347). It will indeed be a main task to establish the status of causal reasoning for circumstances in which system dynamics is being used in a manner consistent with, for example, structuration theory.

A TASK WITH MANY BENEFITS. Such difficulties should not hide the benefits of attempting to link system dynamics with agency/structure integrating theories. Firstly, there

are benefits for social science. Integrative theories arise from an important debate, yet their descriptive style has been heavily criticised (Abell, 1994). If they continue only as the poor relations of economics approaches which have mathematical definitions and employ quantitative empirical data, then their rich agency/structure view may be sidelined. The use of a wide range of data sources and the idea that a model is a 'precise', or clearly stated, theory are but two elements that system dynamics can offer. System dynamics therefore has the potential to preserve the integrative approach whilst responding to the social researchers' call for a more formal style (Coleman, 1990; Hage, 1994).

What benefits flow to the system dynamics field? The importance of integrative theories in social science has been emphasised. If system dynamics can contribute to this debate then it will be at the centre of innovative attempts to understand social systems, the claim that the field always makes. It will also discover a vast array of fascinating phenomena and problems to model.

New suggestions for system dynamics method

It is now possible to bring together the three analyses in this two-part paper to make some over-arching points about how system dynamics could build on this theoretical work to locate itself more firmly within the various social sciences. These are framed as suggestions, each of which has a brief explanation.

Suggestion 1: Communicate better and clarify the social theory

The guiding view in the field when it comes to communicating with other disciplines is that doing good work is the best explanation of what system dynamics is. There is much wisdom in this. However, when good work attracts external enquiries it is important to be able to take matters forward by describing the basis of the approach. This must be done in terms that are, at best, understandable and exciting and, at least, not confusing and off-putting. However, system dynamics is strongly shaped by its engineering roots (Forrester, 1960; 1980; Richardson, 1991). As a result, system dynamicists frequently do not to speak a language that communicates well with social scientists.

For example, failing to articulate a clear social theory of system dynamics - treating it merely as a 're-craftable method' in which model building is as 'friendly' and socially contingent as is necessary for acceptance - is dangerously ambivalent and rootless. Outhwaite describes how "System theory has slid rather easily from an empirical realist concept of structure to something much more like a loose modelling concept ... The trouble with such a ... laid-back approach to theorizing is that it tends to dodge questions of social ontology ... 'systems theory with a human face' ... [is] theoretically unsophisticated but currently favoured ... [in] management studies and organization theory" (Outhwaite, 1990, p.71). This is a jejune stance for the field and communicating it to others is unlikely to produce interest or respect.

Similarly, this paper cites various descriptions of the field that seem extreme, naive or simply confusing to social scientists. The strength of system dynamics work is probably not conveyed when the concerns of potential co-researchers are not grasped. Using terms in a conventional social scientific way is important; some of the determinism criticisms would not have arisen if the field had been a little more judicious in its language.

Establishing and communicating a clear view of the assumptions underlying system dynamics does matter. An explicit social theoretic grounding provides established terms of communication and a position from which to argue for the advantages of good, practical system dynamics modelling work.

Suggestion 2: Respond confidently to the critiques of traditional social system theory

Grabbing for the clarity and security of functionalist sociology as the right social theory for system dynamics is an option but it requires knowledge of previous failings. Social system theory - that of Parsons in particular - though popular in the 1950s and 1960s, has fallen into dis-favour (Mills, 1959). Beyond its grand theoretic stance, the major criticisms concern: the practical relevance of its abstract concepts, difficulties of empirical measurement, the emphasis on equilibria and social order, its poor handling of purposeful action and, finally, its assumption of value consensus and lack of conflict. Those wishing to locate system dynamics purely within functionalist sociology must be sure to distance the field from this inherited dis-favour.

However, 'Broad SD' can indeed make an excellent job of distancing itself from such dis-favour, taking on the above criticism point by point. Firstly, all types of practice stress the practical relevance of a study, how it should lead to increased understanding and actual system improvement. Secondly, all variables within models are required to be meaningful and measurable (with a catholic view of what constitutes data). Thirdly, the field is centred on disequilibrium analyses. Fourthly, models do not presume to be a complete representation of human agency, merely a vehicle for rational debate involving a range of criteria and perspectives. Finally, the engaged form of modelling that Forrester advocated means that although a degree of accommodation regarding what is modelled must exist, a range of judgements can nevertheless be illuminated by the modelling process.

The position that the field might adopt fits well with the observation that, "with the exceptions of economics, the social sciences which have best survived the antipositivist challenge have been those which have thrown off Vienna Circle-style methodological restrictions while going on to build formal models around 'softer' data" (Collins and Waller, 1994, p. 22). So, to avoid being seen as merely Parsonian systems theory brought to life on a computer, system dynamics must offer a confident response, emphasising and maintaining its shift away from objective extremes. It need not be timorous in so doing but in the absence of such a response the field is unlikely to make headway in social science circles.

Suggestion 3: Avoid pure subjectivism - but learn from it

The forms of practice earlier called 'Agency Dynamics' are probably a blind alley for the field. Without disparaging the theoretical or practical value of social theories or systems approaches based on pure subjectivism, this is no place for system dynamics. The field would have to strip away most of what is distinctive and - more to the point - effective in order to ground itself in such theories. An example of such extreme thinking in the case of interpretivism (Lane and Oliva, 1998) reveals a form of validation, an ontological status for models and many other attributes that are probably too alien for most practising system dynamicists.

This does not mean that these schools have nothing to contribute. It is correct to see the identification of the problem focus as a matter of social negotiation (*ibid.*), to try to use an explicit analysis of power in groups (*ibid.*), to accept that many modelling judgements are mediated by personal subjectivity (Vennix, 1996) and to see that implementation requires both the creation of a meaningful description of the problem (*ibid.*) and a compelling vision for where the group wants to be (Senge, 1990). These insights can be integrated into system dynamics by respectfully considering the critiques offered by other social theories - and by following the final suggestion below.

Suggestion 4: Develop an agency/structure integrative grounding

This last suggestion is, in fact, one way of implementing the previous three. By explaining the range of practices that was unearthed earlier, it offers a social theoretic grounding for system dynamics which does indeed break through the paradigmatic incommensurability arguments traditionally employed (Keys, 1988).

Exploring the similarities between system dynamics and any of the agency/structure integrating theories described above, and then studying specific phenomena using that theory, would provide a powerful route for the field into the centre of social science. The idea that system dynamics might be used in a way consistent with any of these innovative theories may be a bold conjecture (Lane, 1999a; 1999b) but it does finally credit to the field a social scientific importance which the profoundly different worldview of the feedback perspective has always deserved. The reasonableness with which many readers will have greeted the descriptions of these theories is an indication of the many similarities between them and system dynamics. In many ways, Forrester proposed an agency/structure integration theory of his own, and before that debate really got started in social theory.

The creator of structuration theory has said that one of the primary tasks of social analysis is the, "explication of the production and reproduction of society as the accomplished outcome of human agency" (Giddens, 1976, p.170). System dynamics is in a unique, privileged position to offer such an explication, using a powerful formal modelling approach that could generate excitement at the heart of social science

Finally, the project suggested here is in no way a distraction from business strategy. A richer view of large scale social system effects is of crucial importance to all business strategy since, "No matter how successful you are in transforming the behaviour of a single business client, the client is still forced by the larger system into behaviours that are disastrous for society (and ecosystems) as a whole, and therefore, after a lot of long-term feedback loops come home to roost, disastrous for that business as well" (Meadows, 1998). From its beginnings system Dynamics has had the ambition to deal with such large scale issues and, indeed, has done so before.³ Integrative theory could help it to continue to do so.

Conclusions

The research reported in the two parts of this paper was initiated by a wish to examine and strengthen the social theoretic grounding of system dynamics. The author's interest was created by comparisons between system dynamics and the problem structuring methods of 'soft' OR (Lane, 1994). However, recognition of the need for some contribution of this nature is long-standing, Forrester himself observed that:

"System dynamics needs a broader and deeper debate about its underlying philosophy, the contrast with alternative philosophies, the nature of knowledge, the role of subjective and observational information, and the criteria for judging validity."

- Forrester (1980, p. 15)

This present author's research project has produced a number of intermediate findings (Lane, 1995; 1999a; 1999b; 2000; Lane and Oliva, 1998) but the work presented here allows some clear conclusions to be advanced.

The first issue concerns the social theoretic assumptions underlying system dynamics. The Burrell and Morgan framework (1979) is widely employed in both OR and systems science as a means of organising the traditional positions on social theory. It was therefore used in this paper to try to answer the question: How do the ideas of system dynamics relate to traditional social theories? The results were problematic. A second question was then considered: Is system dynamics deterministic? The resulting analysis exemplified the difficulties of trying to

probe system dynamics with this paradigmatic approach. The conclusion that was drawn at the close of Part I of this paper was this: notwithstanding its effective use elsewhere, traditional, paradigm-based analysis does not offer a sound theoretical home for system dynamics.

The paper continued in Part II by considering whether system dynamics relates best to the theories which seek to integrate those views based on the actions of individual human agents with those views which emphasise structural constraints. The question being considered is: The agency/structure debate - opportunity for system dynamics? Although many theoretical difficulties remain, a firm conclusion is that these theories offer an appropriate home for system dynamics. Furthermore, they have the potential to generate a string of exciting and innovative modelling tasks, tasks which will allow researchers to display the sort of empirically-grounded and practically-minded approach that is the strong heart of system dynamics.

Taken together the three questions considered in this paper are of general significance for system dynamicists. However, the main purpose of this two-part paper is to explore system dynamics and to present its ideas in ways which are meaningful to social scientists. This leads to a final conclusion - a call to arms. The present, majority concern of the field may be the dynamics of business strategy. However, the field has the potential to contribute greatly across a much broader range of problems in the social sciences. The four suggestions above are aimed at spreading the field in a way which has a sound theoretical base as well as a practical, empirical stance. Presented in the right way, the formal yet contingent feedback causality thinking that system dynamics has to offer should diffuse widely in the social sciences. After all, some of these researchers do live by the motto, *rerum cognoscere causas*.⁴

Notes

- . Although the main ideas of the first paper are recapitulated here, readers are directed to Part I for the detail of these arguments.
- ¹. This question was first posed in Lane (1994).
- ². Note that the usage of 'integrative' from hereon in the paper refers to the unification of agency theories and structure theories. This is quite different from the earlier usage, based on Burrell and Morgan (1979).
- ³. The global modelling work come most readily to mind. See, for example, (Forrester, 1971; Meadows, Meadows, Randers and Behrens, 1972; Meadows, Meadows and Randers, 1992)
- ⁴. The heraldic motto of the London School of Economics and Political Science, London University.

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