The Effect of Linguistic Structure on the Analytic Paradigm of System Dynamics

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ABSTRACT

The purpose of this research is to describe the impact that linguistic structure has had on the method of modeling in system dynamics. In the structuralist framework, language is viewed as a system of signs which structure our patterns of thought and influence our behavior. Learned languages are incorporated into the structure of the unconscious which then contains and constrains the capacity for communication and discourse. Linguistic systems are not isomorphic. Thus, when the language used in communicating social, political and economic ideas changes, (i.e., from verbal to static linear mathematics; or from verbal to dynamic nonlinear mathematics), this affects the theoretical structure of the discipline. The symbolic linguistic structure employed in system dynamic models offers a powerful alternative methodology for scientists to investigate social reality.

INTRODUCTION

Many writers have attempted to attend to the epistemological questions concerning the role of mathematics and its affect on knowledge of social systems. A sample of this literature would include: Caldwell (1982), Dennis (1982), Fritz and Fritz (1985), Fusfeld (1980), Hardy (1978), Katorizian (1980), McCloskey (1985), Mirowski (1987), Quine (1960), and Samuelson (1952). These authors (and many others) have recognized the constraints imposed by the variety of verbal and non-verbal language systems. In practice, social system modelers seldom attend to the impact linguistic structure has on their working analytic paradigms. Even less attention has been applied to the comparison of various nonverbal linguistic structures employed in social system modeling. One notable exception is Meadows (1980), who without the use of explicit linguistic vocabulary covers several of the critical issues.

The primary differences between languages is not the symbols they use or the meaning expressed in the symbols but in their fundamental structures. For the structure or syntax of two languages to be identical or isomorphic, one must be able to place their elements in a one-to-one (and onto) correspondence. The obvious differences between a natural language and mathematical language is in the richness of vocabulary and complexity of syntax of the former and the poverty of those in the latter. Barbut (1970) argues that this opposition points up the enormous efficiency of mathematical models, a simplicity rarely encountered among the human sciences. The language of mathematics is employed at the expense of a reduction in phenomena to which those models may be applied. When reality is complex, symbolic language retains only certain characteristics of the mental model translated through the natural language system; those characteristics which matter most.

This paper will address the relative utility of employing the linguistic structure used by system dynamics compared to translating the modeler's perception of reality into other symbolic language systems. The first section will review the relation of language to the method of scientific inquiry. This will include a discussion of the debate over the problem of translating natural languages into symbolic languages for the purpose of evaluating policy alternatives of social systems. The final section of the paper will specifically identify some of the differences between the imposed linguistic structure of system dynamic models and the symbolic language systems often employed in orthodox economic analysis.

LANGUAGE AND EPISTEMOLOGY

Epistemoligists have contributed much to the understanding of the problem of scientific description. The relationship between the "truths" of a science and the descriptive schemata or "language" used to arrive at and to describe these "truths" has broad implications for the focus and direction of that science. Anglo-American social scientists, being in the tradition of the British epistemologists Karl Popper and Thomas Kuhn, have largely ignored this problem of language as they tend to view the direction of science as a result of the conscious choices of scientists. System dynamicists have employed the refutationist approach developed by Popper in order to show that the method of system dynamics offers a large number and variety of "points of contact" between theories and reality which represent genuine possibilities of exposing errors in the theory (Bell and Senge, 1980), while others have employed the logic of Kuhn's paradigmism in an attempt to compare the problem-solving qualities of system dynamics and its leading competitive alternatives to modeling social systems (Meadows, 1980, Bell and Bell, 1980).

Some philosophers such as Gaston Bachelard, Georges Canguilham and Michel Foucault, see the movement of science as relatively autonomous, proceeding by reorganizations, ruptures, mutations and inseparable from its cultural frame. Scientists are not the cause of scientific practice, only agents, subject to the external determinations - social, economic, ideological, and political. Bachelard maintains that the scientist constantly comes upon epistemological obstacles which are crystallized and systemized in philosophy and which produce braking effects in scientific practice. The epistomelogical obstacle emerges every time a pre-existing organization of thought is threatened, that is it appears at a point where rupture with the past threatens. Its effect is to patch up, to displace the question before it is posed, to prevent the question from being posed. These obstacles are the perceptions, representations, values and attitudes of a given society that intervene in science through language. The images, metaphors, or in Bachelard's terminology "traces" present in ordinary language inhibit the progress of science as they embody a certain representation of the real, a reality offered to investigation. Expressions such as "the rising/setting sun", remnants from pre-Newtonian science, permeate the unconscious and result in the substitution of imaginary questions for the real questions by which a science progresses. Bachelard states that the dangers of metaphors for the formation of the scientific mind is that they are not always passing images; they press on towards autonomous thought.

Foucault (1970) relates science and the discursive practice of a society at a given point in time. Science is defined by the perceptual field of a given era - what is visible and invisible, thinkable and unthinkable, stateable and unstateable. The objects that will or will not acquire scientific status are dependent upon an ensemble of interlocked and hierarchically structured discursive practices. As the discourse of a given science or discipline acquires power and status, it affects the perceptual field of other disciplines. It begins to function as the norm, governing attitudes with respect to real objects and problems. According to Foucault it is the structure and hierarchical relations of discursive practices, which he calls the discursive formation of an era, which assign the forms and limits to theory (Lecourt 1975).

The existence of a pure intellectual space in which the concepts of science are worked out by a body of scientists is pure fiction to these epistemologists. The ideological values of the social formation in which the science is inscribed and the language through which these values are passed permeate the consciousness of the body of scientists and render their choices to a limited set of predetermined paradigms.

RHETORIC IN ECONOMICS

If progress in social sciences is not founded on the existence of a pure intellectual space but rather on the ideological values of the social formation in which the science is inscribed, what then is the source of 'progress'? Donald McCloskey (1985) has raised the argument that progress in economics comes through rhetoric, employing the metaphor. Neoclassical economic theory is founded upon a single mathematical metaphor which equates "utility" with the potential energy of nineteenth-century physics. McCloskey states the methodological 'Commandments' of modernism in economics and other sciences, which include, along with others (pp. 7-8): (1) Only observable implication (or predictions) of a theory matter to its truth, (2) Observability entails objective, reproducible experiments, (3) Objectivity is to be treasured; subjective "observation" (introspection) is not scientific knowledge, because the objective and subjective cannot be linked, (4) Kelvin's Dictum: "When you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind." (Jocob Viner adds: "Yes, and when you can express it in numbers your knowledge is of a meager and unsatifactory kind." Frank Knight adds: "Yes, and when you can't measure, measure anyway.", and (5) It is the business of methodology to demarcate scientific reasoning from nonscientific, positive from normative. These commandments thrive among applied, not theoretical, philosophy, among professional economists, not professional philosophers. McCloskey argues that few of these commandments are believed by any professional philosophers and many believe none of them. However a majority of social scientists believe them all.

Modernism promises knowledge free from doubt, metaphysics, morals, and personal conviction. Clearly it cannot deliver what it promises. McCloskey follows the growing number of professional philosophers who believe that scientific knowledge is not very different from other 'knowledge'. It derives from rhetoric. The laws come from a tradition of conversation, where "quantitative studies ... are explorations with the aid of a theory, searches for numbers with which to make specific a theory already believed on other grounds" (p. 19). We come to "know" in many ways, not always reducible to sight or synthetic a priori. To McCloskey, what distingushes good from bad in learned discourse is the earnest and intelligent attempt to contribute to a conversation, richly founded in the oldest of philosophical doctrines dating back to Plato. Among scientists the conversations overlap enough to make one almost as sure about neighboring fields. The overlapping conversations provide the standards. In economics it is a market argument. This reduces the need for philosophical lawmaking or methodological regulation.

Rhetoric then is the study of how people persuade: the art of probing what men believe they ought to believe, rather than proving what is true according to abstract methods. Philip Mirowski (1987) expands on this concept by arguning that the prevalence of methaphor and analogy in the history of sciences is no accident (p. 79). Increasingly mathematics became the preferred mode of communication by every discipline which attempted to gain the status and legitimacy of the Cartesian natural sciences. Mathematical formalization provides a method for the transfer of metaphor and these metaphors provide ready-made linkages of concepts, with ready-made reasons to justify those linkages. By importing a mathematical metaphor from another discipline, the scientist has a web of propositions which have withstood testing, elaboration, and criticism in a different context. Metaphorical analysis lifts the web of propositions from one context and drapes it over the phenomena in another context.

For Mirowski the coherence to neoclassical economic theory grows out of a single metaphor, a mathematical metaphor. The early neoclassicals took the model of "energy" from physics, changed the names of all the variables, postulated that "utility" acted like energy, and then named the new analogy pure economic market theory. Some of the old propositions may not fit the new context. Rather than abandon the entire metaphor, the economist decides which conceptual aspects are to be adjusted and which are indispensable.

LANGUAGE THOUGHT AND REALITY

To understand how language influences scientific investigation it is necessary to consider the relationship between language and perception, language and thought, and language and society. There is no pure act of perception without thought. The flux of experience must pass through the interpretative schemata of the mind. Language does not mirror the mind but rather it is language which gives structure and form to our thoughts. What we see and think tends to be limited to what we can say. Perceptions and thoughts are also socialized because the language that gives them form is immersed in the on-going life of a society and reflects the consciousness of that society. "Languages are systems of categories and rules based on fundamental principals and assumptions about the world." (Kress and Hodge, 1980, p. 5)

In the 1830's Wilhelm von Humbold postulated that one thinks in forms limited and determined by the forms of one's native language. In the 1930's Benjamin Whorf linked the structure of language with a particular world view and sought to reveal the metaphysics implicit in the structure of Indo-European languages (Coetzee, 1977). The tendency to perceive the universe in terms of objects and actions rather than states is imposed by the use of a language which breaks down reality in terms of subjects and verbs. The standard order so prevalent in English (Subject-Verb-Object) imposes the reading of causality and temporality into experience whereas these meanings would not necessarily be transmitted in other families of languages. The Subject-Verb order is metaphorical because it imposes a temporal-causal order over the syntactic order.

Modern science as we know it in the Western World mirrors the structure and processes of Indo-European languages in that it seeks to give a systematic account of reality by linking events to a network of causal relations and to structures of objects and forces. Language provides a theory of reality which is superimposed on the scientific theory it helps to articulate. There is evidence that Newton struggled with language while attempting to explain the law of gravitation. The controversy that ensued over this law (and which became a cause celebre in the history of science) was due to language (Fritz and Fritz). By using the standard syntactic order of Subject-Verb-Object, Newton was obliged to assign temporal-causal relationships to heavenly bodies.

Newton attempted to eliminate metaphorical content in his scientific discourse by using two linguistic techniques. These techniques have been adopted by the modern scientific community and contribute to the scientific discoursive style as we know it: the predominate use of passive constructions and nominalisations. Passivisation is a transformation of the basic transactive model (Subject-Verb-Object) in which there is a source, a verbal process, and an affected entity. The transactive model indicates clearly the causal process as all agents in the process are specified. When this model is transformed into a passive construction the source or agent of the process may be omitted. This information is lost or obscured. The passive construction enabled Newton to avoid philosophical questions about causality by omitting the syntactic agent. Nominalisations reduce both agents, source and affected entity, and the process to a state, thereby eliminating all temporality and causality.

When causal and temporal relationships are blurred, discourse is vague or ambiguous as the source and consequence of phenomena. "The science that proceeds through non-transactive models will tend to be a large collection of particular facts about self-caused events which co-exist" (Kress and Hodge, p.39). Kress and Hodge maintain that such a style is functional for the community of scientists in that it allows one to avoid making distinctions when accounting for data beyond the scope of theory.

Labov adds that groups create kinds of languages which serve to reinforce a sense of identity and exclude others. The distribution of power is reflected in and sustained by differences in language. Scientific language also sets up a barrier around the privileged knowledge of its community of specialists. The repetitive use of the expression "given . ." is a case in point. What is given? Who determines the goals? How is the theory defined? What is the status of the investigator? This common linguistic device can serve to remove important questions from public consideration (Kress and Hodge).

LINGUISTIC STYLE, THEORY, IDEOLOGY

Linguistic transformations are used to effect theoretical transformations and are not free of ideological determinations. "Anomalies constantly face scientific theories and are resolved either by changing the theory or by reinterpreting the event. Awkward facts may be successfully denied, suppressed or reinterpreted (through linguistic devices)." (Fowler, et.al. 1980 p.63) Linguistic forms allow significance to be conveyed and to be distorted. In this way the hearer/reader may be manipulated and informed. What is significant is the disappearance of deleted material and its non-recoverability in the text. "Presenting anything in or through language involves selection -- how the speaker/writer chooses to present reality" (Kress and Hodge p. 15). A profession is not self-contained. It has links with institutions, groups, and movements. Its credibility depends on which forces it gives expression to and to which institutions or segments of society it identifies with, supports and respects. Language serves to confirm and to consolidate the organizations which shape it.

Linguistic styles are socially determined patterns of language. Preferred syntactical arrangements can encode a world-view without the conscious choice of the speaker/writer. World-view comes from relations to institutions and socio-economic structure of society but is facilitated and confirmed by language use. We are socialized into holding theories and judgments because of the social meaning, reinforced in the lexical and syntactic structures we use. It is unnecessary to assume that groups deliberately construct a 'syntax of mystification'. Once a style comes into existence it becomes appropriate for expressing a given content. Groups do not consciously recognize the purposes they encode in language and the aims which they mediate in their professional capacities may not coincide with their beliefs or sympathies.

NATURAL LANGUAGE VERSUS MATHEMATICS

Adopting mathematics as an instrument of investigation and communication of scientific research does not negate the problem. Maher asserts that mathematics and logic are only "parasitic systems", outgrowths of the processes of natural language. He sees natural languages as palimpsets as they bear the imprint of different eras. Language surface, its forms and structures, reflects not the present but the past. The grammatical system tends to persist indefinitely and will in time cease to symbolize the cultural forms which motivated its existence. It is the decalage between the surface structure and the shifting values that motivated it that creates the metaphor.

Mathematics is also metaphorical in that it grows out of abstraction. There is no pure abstraction as there is no pure perception. "The equation, the syllogism, all their complex superstructures . . . are intrinsically nothing but metaphors. The source of those metaphors is figure-ground differentiation of configuration, with abstraction of certain salient features, preceding from other features of the bundle." (Maher 1977 p. 8)

No matter what linguistic medium is adopted, scientific description will remain problematic. In reflecting on this problem one must consider two questions. What is the relationship between the linguistic medium and the material and what does this medium impose on the material. Regnier (1974) states that this relationship is always characterized by transformation and deformation. A model is the interpretation of a theory and must furnish a description which is not contradictory with the theory. All aspects of phenomena are not represented in a model. One chooses properties which present a certain coherence and one negates the accessory. What the model retains and what it ignores poses the problem of what is pertinent and what is negligable. Judgment and interpretation are closely linked with perception, linguistic conditioning and ideology.

A descriptive medium, whether natural language, logic or fields of mathematics, has certain semantic limits that orients research with the boundaries of its own particular representation of the world. Scientific output may be viewed as a compromise between the necessities of the descriptive medium and those of the real. Much of the debate over the mathematical modeling methods used to represent social systems stems from the modeler's world view (Meadows, 1980). System dynamicists assume that the systems are primarily closed, interacting with the environment which influences it, and are more interested in the dynamic path of a response than the end state. Orthodox economics, through econometric models assume that the world is dualistic and open. This means that the environment (markets, government action, foreign influences, or institutional settings) delivers inputs (exogeneous) to which the system provides specific responses. System dynamicists believe the problems are predominately addressed as long run issues, while the microscopic view of econometrics confines itself to the short run. Meadows (p. 237, 1980), summarizes several characteristics useful for comparing modeling paradigms. However, linguistic structure is not included in the comparative categories.

In order for the linguistic structures to matter between modeling methods, we must first show that they are different. That is that the mental model in our head is originally formed in a natural language system, then translated into a symbolic language structure consistent with the quantitative modeling tool. Further that the translation of the mental model differs depending upon which symbolic language system is receiving the model.

NATURAL LANGUAGE SYSTEMS, MENTAL MODELS AND MATHEMATICS

By the end of the 18th century the Newtonian scheme was decisive in convincing the world that nature is mathematically designed and that the true laws of nature are mathematical. Newton's amazing contributions were made possible by his reliance on mathematical description even where physical understanding was completely lacking. Newton placed mathematical description and deduction at the forefront of all scientific accounts and prediction. While this position was attacked by David Hume and others, Immanuel Kant affirmed that all axioms and theorems of mathematics were "truths" (1781). However, Kant argued that science was a world of sense impressions arranged and controlled by the mind in accordance with innate categories such as space, time, cause and effect and substance. "The mind contains furniture into which the guests must fit" (Kline 1980 p. 77).

The development of non-Euclidean geometry finally led to the recognition that mathematics was not a body of truths. The debate over the "anticipatory function" of the language of math continues (Kuyk 1977 pp. 141-170). That is, does the axiomatic language "run ahead" of verbal language such that the manipulation of a formula leads to a result that could not be thought to be true before the manipulation. Whether mathematics offers a more useful (powerful) linguistic structure for the social sciences is not the issue of this essay. However, those readers interested in the application of this problem in the language structure used in system dynamics are referred to the work of Forrester on the counterintuitive behavior of social systems (Forrester 1971).

The salient point is that orthodox economic analysis adopted the linguistic structure of differential calculus with the "marginalist" revolution in the last half of the nineteenth century. The structure of the adopted calculus resulted in the dominant theoretical role played by a single economic agent. Ideologically, this shifted the focus away from the "political economy" of society to the "economics" of utility maximization by the individual. The analogy used by the metaphor was that an individual's "utility" was like the physical unit of "energy". The new linguistic structure introduced new "words"; derivative and infinitesimal. The marginalists used these to isolate relationships by the necessary linguistic constraint of assuming "other things remain equal" so that the changes in the economic variable on which they focused was not to be systematically related to the variation in the variables they were ignoring. The need for simplification in the new symbolic language structure was invoked to support the position that the assumptions of a theory should be removed from the ambit of criticism. Abstraction assumptions are not an element of the "axiomatic structures" of the theory and therefore may be ignored by the formalistic language of the model. Some believe that the deterministic language of differential calculus and the "representative" individual economic agent were merely expository devices chosen because of their pedagogical utility (Gill 1981 p. 76).

The natural language system of the classical economists represented a different set of meta-assumptions (or methodological priors) than the symbolic language system of the neoclassical economists. Translating mental models into the working models of the discipline led to differences in policy conclusions under the conceptual plane of calculus. System dynamists have recognized that differences in analytic paradigms can lead to differences in policy conclusions (Anderson 1981, and Phillips 1980), although they have not related the meta-assumptions back to linguistic structure.

This pratice of analogical reasoning is not restricted to the activities of mathematics nor neoclassical economics. Indeed the activities of the physicist also consists of the transport of analogy from one domain of science to another. Students of electrical engineering recognize that any mechanical or acoustical system can be reduced to an electrical network and the problem solved by circuit theory, or vice versa (Mirowski 1987 p. 79). The success of the theory of energy was partly due to the capacity to see analogies between phenomena which were previously unrelated. One could state that mass was "like" inductance and that velocity was "like" current. The mathematical formalisms developed in the shpere of rational mechanics could be used to describe other phenomena in novel spheres, such as electricity.

It comes as no surprise to students of system dynamics that their models look like electrical networks and that the first applications of system dynamics to social systems were applied by an electrical engineer, Jay Forrester. The metaphorical analogy of electrical networks to the linkages of social systems was a natural application of the rhetoric of science. The mathematical formalism of electrical circuits provided an excellent opportunity for the transfer of metaphor.

Having established that linguistic structures matter between modeling methods, the next issue is the extent that the translation of the mental models differ when translating from the natural language system into competing symbolic language systems of the receiving quantitative models.

THE TRANSLATION PROBLEM AND MENTAL MODELS

The vocabulary of systems analysis fits the semiofficial doctrine of translation developed by Dennis (1982). This follows the development from the nineteenth century to present that the concepts and propositions of economics could be translated into the symbols and formulas of mathematics. The doctrine has some credibility. Mathematical symbols, formulas and methods do enter into economic theorizing but not in a way as to prove behavioral propositions about human beings and their economic actions. Mathematics, traditionally developed is the logic of numbers and number relations. It is not a logic about events and the conditionality of the occurrence of events (Dennis p. 107). Even though number systems and measurement systems have been shown to be homomorphic relational structures, numerical functional formulas do not express behavioral propositions about events and the contingency of their occurrence (Krantz, et.al. 1971).

Moreover, contrary to Samuelson the syncopation of homomorphic identity found in the translation of natural languages to mathematics cannot yield the "logical identity of words and symbols" (Samuelson 1952 pp. 59-60). Translation of a sentence conveys the same information as the original, in that it expresses the same proposition (Rescher 1969 p. 322). The mere correspondence of synonymous words does not meet the necessary conditions of adequate translation. Thus translation may take on different relative qualities that may range from "naive" to"fair" to "strict" (Dennis, pp. 706-710). Employing special symbolism in scientific work is primarily to achieve notational conciseness as an aid to logical manipulation. Abbreviation through linguistic symbolism does not afford greater degrees of precision than ordinary language, only clarity gained by the use of abbreviated symbolisms. Therefore translation of language systems may be of different quality with the highest quality resulting in the symbolic notation that yields the most clarity in expressing the original propositions found in the natural language. When the propositions being translated are scientific argumentation, the translational adequacy becomes a vital aspect of ensuring the logical rigor of the argument.

One test of the effectiveness of the translation of a mental model into a symbolic linguistic structure is the ability of the receiving structure to use the wide range of information arising from the system being represented. Forrester (1987) has pointed out that system dynamics models use information in a substantially different way from that in other branches of the social sciences. His main argument is that information is available in many forms; the mental data base, the written data base , and the numerical data base. The mental data base contains vastly greater more information than the written data base, with the numerical data base representing only a small fraction of the knowledge people carry around with them everyday. The written and numerical data bases contain only a small proportion of the information needed for constructing a dynamic model. The construction of system dynamics models generally begins with the metal data base. Recall that McCloskey's commandments require measured observable data, which is not a prerequisite when employing the lingusitic structure of system dynamics. With the mental data base containg the bulk of knowledge needed to understand the conduct of human systems, it is logical that any translation of the real social system which employs this rich source to the fullest would out perform an alternative. Information from the mental data base is underutilized in the quantitative models of econometrics and most other social sciences, which are constrained by the use of the numerical data base as dictated by the scientific of modernism. What these alternative translations lack, when they are only based on the numerical data base, is the direct evidence of the structure and policies that created the data.

Recall the previous example of syntactic transformation when Newton adopted the passive construction and nominalisations rather than the basic transactive model (Subject-Verb-Object). The transactive structure of Indo-European languages indicates the causal and temporal processes as all agents in the process as specified. The passive construction enabled Newton to avoid causality and temporality by reducing the source, affected entity and the process to a state. Nominalisations and passivisation may be achieved in linguistic structure by either transforming the existing language system to a non-transactive model or by translating one linguistic system into another while at the same time altering the syntactic order. Both result in obscuring the causal and temporal relationships so that discourse is rendered vague or ambiguous as to the source and consequence of phenomena.

As an imposed value judgment, linguistic translation which results in non-transactive models where transactive mental models were the goal, are categorized as "naive" translations. Natural language translated into symbolic systems that retain the original transactive model meet the necessary condition of "fair" translation. (Here, Dennis' categories are adopted to fit this essay's theme.) It has been argued that orthodox economics, relying on the logical empiricism of statistical (econometric) modeling, achieves the passivisation of theoretical discourse by "nouning" (Neale 1982). "Nouning has contributed to confusion about meaning, and to confusing word order with cause. It is important to distinguish between value as a noun (thing), which it is not, and to value as a verb." (Neale pp. 362-63) In orthodox economics, nouns are explanations: utility, preference, tastes. These are not things but verb processes. A clearer understanding of social systems is achieved by rejecting "nouning" and arguing for "processual verbing". Verbing influences our ideas about cause while nouns exist separately from their being or doing.

Broadly described, econometric models translate natural language systems into symbolic language systems, transforming the transactive structure into passive syntax. At first glance it appears that the causation analysis in the robust literature of probability theory is transactive. However, the question rests not with the power of statistical models but with what is the sentence (represented by an equation) saying. Are econometric models paraphrasing orthodox economics by avoiding the verb processes of the transactive structure? Econometric models are detail decision making based, product oriented, and structured as open systems requiring many exogeneous variables to drive the model (Meadows 1981). When two-way causation does appear as in simultaneous-equation formulation, equilibrium is achieved without temporal analysis. The primary focus of econometric models is on the noun of the equation sentence. In the basic linear open model there is no feedback describing the temporal and causal path that represents the Indo-European syntax of natural language structure. The reduced form estimation process means that econometric models tend to "represent surface phenomena only, with much causal structure implicit" (Meadows p. 229).

The econometric translation has benefited from the recent developments in the theory of measurement. In the modern literature, attention has focused on "the construction of homomorphisms (scales) from empirical relational structures of interest into numerical relational structures that are useful" (Krantz, et.al. 1971 p. 9). The relational concepts of structural identity (isomorphism) and structural similarity (homomorphism) are used to justify "the direct application of computational methods to the results of measurement" (Luce and Suppes 1968 p. 72). The symbolic sentence: $x + y = z$, can serve the dual purpose of expressing 'z' as the empirical result of measurement and the result of numerical computation whereby the abstract operation of addition is performed upon the numbers x and y. The consequence of isomorphism between empirical and numerical relational structures is that the same symbolism may be adopted for both systems. Thus the rationale for the use of numerical algebras to espouse and describe certain properties of empirical relation systems.

The problem of representation is the heart of the measurement development: "When measuring some attribute of a class of objects or events, we associate numbers (or other familiar mathematical entities, such as vectors) with the objects in such a way that the properties of the attribute are faithfully represented as numerical properties" (Krantz, et.al. 1971 p. 1). The problem of representation, while important, is not the source of concern in most social science theories. Most social policy analysis concerns causal connections (or patterns of connectedness) that are open to empirical inspection (corroboration or refutation).

While there are some examples of fair translations employing logical grammers in simultaneous equation econometric models, the dominant linguistic structure of econometric models transform the transactive structure of natural language into a passive structure. Causality becomes the problem of the measurement of probability considered in an open structure (Granger 1969). However as Bell and Senge (1980) have pointed out, if a model includes multiple exogenous time series inputs, disentangling internally generated behavior from externally generated behavior may be difficult or impossible. From the viewpoint of linguistic structure, their conclusion is a logical outcome of avoiding the transactive model of natural language. As such these neoclassical quantitative models can be considered only 'naive' translations of the scientist's mental model.

Simulation testing in system dynamics which reveals flaws or corroborates model assumptions is enhanced by employing endogenous explanations of behavior. Without exogenous time series inputs, a system dynamics model should generate the empirical behavior of interest. An array of simulation tests conducted without time series inputs guarantees that model behavior arises from causal feedback loops. The interactions necessary for understanding the causes of behavior are found within the model structure. This attends to the scientific goal of highly corroborative theories requiring multiple "points of contact" with reality (Bell and Senge). This view of the scientific method defines objectivity in terms of the degree the theory presents opportunities to test it against reality.

The linguistic structure of feedback loop analysis (mathematics of integration used in control theory) provides increasing objectivity. System dynamics has a strict syntax and structure. All models must have the property of closure containing at least one feedback loop. The model closure test requires that "starting from any point in the influence diagram it must be possible to return to that point by following the influence lines, in the direction of causation, in such a way as not to cross one's track" (Coyle 1978). "Closing the loop" can only be accomplished in a temporal setting with an explicit delay intervening between initial action and the resulting feedback. The syntactic structure of the variables (sentence components) is determined uniquely by the type of each variable.

System dynamics has three basic types of variables; rates, levels and auxiliaries. Level variables (an accumulation or integration over time) are stocks (nouns) that change as flows come into and go out of it. Rate variables are the flow, decision, action (verb) or behavior that changes over time as a function of the influence processes. Auxiliary variables are combinations of information inputs into concept (predicates) terms. "Rates" must be the preceding variable of a 'level'. Auxiliary or rate variables may succeed levels. Other combinations are possible, but the syntactic order must remain transactive (Subject-Verb-Object) around the closed loop. This focuses the attention on the general system reaction to general disturbances and on the dynamic path of a response rather than its end state (Meadows pp. 227-28). In Neale's terminology, system dynamics employs the linguistic structure of verb processes rather than "nouning" the hypothesis. The result is a "fair" translation of the natural language system into a symbolic language structure which is more concise and facilitates computer modeling of causal relations.

CONCLUSION

The translation of natural language systems into symbolic linguistic systems cannot produce isomorphic structures. Thus the problem is to minimize the loss of coherence that can result from the transformation of the transactive structure found in Indo-European language grammars into the less causally and temporally explicit form of the passivitive structure. Differences in analytic paradigms can lead to differences in policy conclusions. Some of these differences can be explained by the impact linguistic structure imposes on mental models and quantitative models. As languages are not isomorphic, what is imposed on science by their models will vary. Natural language as an abstract system of classification embodies a theory of reality in its forms and syntax. Groups of languages present a preferred model for interpreting and perceiving phenomena. However, these systems are made actual by human agents in social interaction and is renegotiated in response to forces outside the language system.

Mathematics as an abstract system also imposes semantic limits which orient research. It may, as natural language, be manipulated to present certain points of view. The preference for mathematics over natural language to investigate and explain social science forces may be said to be in part ideological. As in the case of natural language this choice may or may not be conscious. System dynamics employs a linguistic structure which yields "fair" translations from natural language system. This translation provides numerous points of contact with reality and thus offers an opportunity for refutable hypothesis to be tested against reality. This essay has attempted to enhance awareness of the placement of linguistic structure within the methodological critique of the field of system dynamics. Evaluation of the contribution by the discipline should not only include policy and theoretical implications of the field but also methodology, included in which must be a consideration of the linguistic structure.

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