Continuos judgmental models as building blocks for system dynamic models of social systems

Daniel Vekstein Ph.D.

The School of Management, Ben-Gurion University of the Negev, Beer-Sheva 84105, Israel

1. Introduction

Nuthmann (1994) criticized system dynamicists for treating models of social systems with the continuos measurement (e.g., ratio) scales and mathematics (e.g., power functions) typically used in physics and engineering. Nuthmann argued that unless modelers build their models on empirically validated judgmental converters as credible behavioral choice models, they cannot assume they are dealing with anything other than ordinal phenomena. Nuthmann then challenged modelers to provide, and build on, specific evidence that the judgmental phenomena they intend to consider in their models behave according to ratio scales. This paper takes up this challenge.

2. Behavioral Choice in Real Social Systems

In general, theories of choice have dealt with the problem of behavioral allocation. In particular, expected utility theory (allocation based on the probabilities of prospects) and discounted utility theory (allocation based on the timing of prospects) address continuous choice behavior—that is, behavior maintained by schedules of reinforcement (rewards and punishers). These theories predict how different, multiple or concurrent schedules of reinforcement—as a complex stimulus structure for decision makers—would affect the steady states of behavioral responses (e.g., Prelec and Loewenstein 1991). Vast empirical research on behavioral allocation, under experimental and natural conditions at the individual and group levels of analysis, shows patterned stimulus-response relationships (e.g., Epelbaum 1990; Hamblin 1979, 1971; Rainwater 1974). These patterns conform to ratio scales (not to ordinal scales) and are described adequately by power functions (not by step functions which are appropriate to ordinal phenomena). In general, power functions and ratio scales are appropriate to empirical data on human choice because it seems that the principle of "matching" is the routine response mechanism of decision making under uncertainty. Most life situations faced by humans are complex, involving multiple and concurrent (e.g., variable-ratio and variable-interval) schedules of reinforcement, hence uncertainty (e.g., Prelec and Loewenstein 1991). In these situations, humans seem to follow the adaptive strategy of matching the frequency of their behavioral responses to the frequency of reinforcement as they perceive it in the whirls of environmental change. Thus, in most real social systems, relative change in human response becomes, on the average, proportional to relative change in environmental stimulus. This is the empirical regularity that has been typically described by power functions as noted above (e.g., Hamblin 1979).

3. An Example: A Model of Organizational Growth

A simple system dynamic model of firm growth (which is described in details in the conference presentation and in the fuller version of this paper) illustrates the appropriateness of behavioral matching equations for system dynamic models of social systems. The model includes four sectors:

3.1. Environmental change: Hamblin et al. (1973) provide extensive supporting evidence that long-term trends in innovation phenomena at the macro-level of analysis (involving social, political, technological and economic change) can be reasonably approximated by an exponential process. This macro-social process often shifts the basis of competition for firms in an industry. Top managers tend to respond differently to these changing environmental conditions (D'Aveni and MacMillan, 1990). Obsolescence is a strategic response by firms to environmental change, and firms differ in this response even under exponential rate of environmental change.

3.2. Obsolescence: It is a relatively patterned judgmental response to environmental change. Obsolescence involves top management's awareness of the extent to which existing firm's knowledge is aging knowledge. Management's judgment is often made in face of the novelty of ongoing environmental change. Environmental change is a source of opportunities and potential threats for business firms. Thus, firms often scan their environments in search for potential reinforcement. Since environmental change involves multiple and concurrent schedules of reinforcement, firms face a continual condition of uncertainty. Under this condition the relationship between obsolescence and environmental change is described by firm-specific power functions, which are appropriate to the "matching" stimulus-response relationship noted above.

3.3. Knowledge: The accumulation of knowledge in an organization is conceptualized in terms of two related but subtly distinct organizational learning processes: 1) an innovation process through which organizational members produce new knowledge from experience in cross-fertilization of various streams of previously accumulated knowledge, and 2) and intra-organizational selection process that results from top management's judgment about obsolescence. Thus, the selection process involves identifying, defining and ultimately discarding obsolete knowledge in face of environmental change. The parameters for the rate of the innovation process and for the rate of the selection process, largely determine the dynamics of knowledge accumulation in the organizational system under consideration.

3.4. Firm performance: It involves turning accumulated knowledge into actual economic behavior—producing for industrial markets in the present case. Change in performance may be subject to delay (days, weeks or months) after a certain change in knowledge occurs, but over long periods of time (months or years) relative changes in performance are proportional, on the average, to relative change in knowledge. This empirical regularity has been typically described in the literature by learning curves often specified by power functions (e.g., Adler 1990; Hamblin 1973). Thus, a power function was used to model the relationship between knowledge and performance. Since not all accumulated knowledge can be conveyed into performance (e.g., tacit knowledge can hardly be transferred), the exponent of this relationship is typically less than 1.0.

4. Simulation Results and Conclusion

The growth model was constructed with the *ithink* software and simulated under various parameter conditions. Its external validity was examined on various time series data gauging firm growth (e.g., General Motors, 1946-1990, Sears Roebuck 1919-84.) The results show that the model behaves consistently with actual data in all cases, and suggest that the underlying behavioral choice equations are empirically adequate building blocks for this model. Alternative runs were made under similar parameter conditions, but with a step function used instead of the power function to specify the "obsolescence" sector of the model. Although the alternative results, in general, could be successively approximated to actual data by increasingly fine-tuning the step function with additional small stages, this procedure turned out to be quite arbitrary and could be continued *ad-libitum* without using orderly steps and sizes of successive approximation. This procedure, which was used by Nuthmann himself to base his criticism, would not add credibility to the system dynamic model in which it is used, more than using ratio scales and power functions in that model. These functions and scales, at least, have been resting on solid empirical grounds of research and evidence as noted above. The results of this study suggest that Nuthmann's criticism may reflect what he feels is a common practice among system dynamicists—to build models without referring to the research literature that supports the use of ratio scales and underlying behavioral choice models as noted above. This possible neglect, however, does not justify, as Nuthmann would have us to believe, that system dynamic modelers should proceed to assume that human judgment can be appropriately modeled as ordinal phenomena with step functions as their specification. Rather, modelers should better look in the literature for empirical supporting evidence of ratio scales and power functions. If they do so, they will conclude, as this study does, that continuos quantitative judgmental models are indeed theoretically adequate and empirically valid building blocks (subject always to further improvement) for genuinely credible system dynamic models of social systems.

References

Adler, P. S., and K. B. Clark. 1991. Behind the Learning Curve: A Sketch of the Learning Process. *Management Science* 37: 267–281.

D'Aveni, R. A., and I. C. MacMillan. 1990. Crisis and the Content of Managerial Communications: A Study of the Focus of Attention of Top Managers in Surviving and Failing Firms. *Administrative Science Quarterly* 35: 634–657.

Nuthmann, C. 1994. Using Human Judgment in System Dynamic Models of Social Systems. *System Dynamics Review* 10 (1): 1–27.

Epelbaum, M. 1990. Sociomonetary Patterns and Specifications. *Social Science Research* 19: 322–347.

Hamblin, R. L. 1971. Ratio Measurement in the Social Sciences. *Social Forces* 50: 191–206.

———. 1979. Behavioral Choice and Social Reinforcement: Step Function Versus Matching. *Social Forces* 57: 1141-1155.

Hamblin, R. L., R. B. Jacobsen and J. L. L. Miller (1973). *A Mathematical Theory of Social Change*. Wiley, New York.

Prelec, D., and G. Loewenstein. 1991. Decision Making Over Time and Under Uncertainty: A Common Approach. *Management Science* 37: 770–786.

Rainwater, Lee. 1974. *What Money Buys*. New York: Basic Books.