HYSTERESIS

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Economists use the term 'hysteresis' to denote the persistent influence of past economic events. This usage recalls the origin of the term in the physical sciences. The 19th century physicist James Alfred Ewing coined 'hysteresis' to denote the persistent effects of the temporary exposure of ferric metals to magnetic fields: subsequent states of the metal were best understood by reference to the past. The general idea was that a transitory disturbance of a system can cause a persistent change in the description of the system. More specifically, the current value of an endogenous variable can depend on past rather than present values of some explanatory variable.

To anyone accustomed to modeling dynamic interactions with systems of ordinary difference or differential equations, the general notion of hysteresis does not seem exceptional: past and present states of such systems are always related by the rules of motion of the system. One may also readily accommodate the specific notion of dependency on the past. Consider the problem of modeling a transitory disturbance of a dynamic system characterized by autonomous (time independent) rules of motion. Given a disturbance that occurs during the time interval $[t_1, t_2]$, one might model the persistent effects of this transitory disturbance in at least two ways. First, the disturbance may be incorporated directly into the description of the system in order to yield a non-autonomous system. Second, the autonomous system can simply be analyzed subsequent to the disturbance; the state of the system can then be explained in terms of its state at t_2 and the passage of time. In the first case, the resulting description (solution) of the post-disturbance system will involve a direct reference to the disturbance. In the second case, the persistent influence of the disturbance is felt through the lasting importance of the state at t_2. In these contexts, using the term 'hysteresis' accomplishes little more than emphasizing that a system is truly dynamic.

When economists use 'hysteresis' simply to contrast dynamic with static systems, they employ a rhetorical device to draw attention to a perceived novelty. For economists accustomed to the inherently static general equilibrium framework deriving from Walras, perhaps any notion of important historical linkages will be novel. However, economists do not generally consider the influence of lagged income in popular modifications of the Lucas supply curve to constitute hysteresis. In contrast, dependence of the "natural" rate of unemployment on the history of unemployment is considered hysteretical: it is a particular influence of the past on the present that is generally absent in economic models. Similar considerations are involved in Elster's discussion of the relationship between the superstructure and the economic basis. Elster (1976) suggests that the standard interpretation of historical materialism links the current superstructure, s_t, to the current economic basis, b_t. He contrasts this with an hysteretical variant, $s_t = s^1(b_t, s_{t-1})$, wherein the current superstructure depends not only on the current economic basis but also on the past superstructure, s_{t-1}.

Although the formalisms of discrete time analysis may seem to suggest otherwise, hysteresis is not a matter of unmediated action at a temporal distance. The past can influence the present only through traces left in the present, for the very nature of causal explanation implies that an event at time $t-1$ cannot

affect events at time t_2 unless it also affects events at all $t \in (t_1, t_2)$. A complete description of the present—without reference to the past—is *logically* adequate for prediction in any causal dynamic system. However, such a description may not be practicable. In the terminology of Elster (1976), epistemological hysteresis characterizes dynamic systems for which no ahistorical description is feasible. The impossibility of ontological hysteresis, in the sense of unmediated action at a temporal distance, does not rule out the possibility of epistemological hysteresis, in the sense of the fundamental historicity of the system from the perspective of the investigator.

In applied work, epistemological hysteresis is pervasive and important. For example, a researcher studying the wage determination process can observe the past history of aggregate unemployment but not the expectations and current human capital of all the individuals in the labor force. In this case, as in James Alfred Ewing's original work, the researcher can refer to the macro-past of a system but not to the current micro-state. When appropriate causal links exist between the observable past and the non-observable current state, an hysteretical description of the macro-system is useful for explanation and prediction. Theoreticians, in contrast, do not generally model hysteresis in this way. Indeed, *prima facie* such a project appears to conflict with the very notion of a formal model of hysteresis. Perhaps for this reason, the concepts of hysteresis current in the social sciences are weaker than that of epistemological hysteresis.

Explicit social science models of hysteresis involve dynamic systems that—through appropriate redefinition of the state of the system—may be readily expressed entirely in terms of the present state of the system. Motivations for not expressing the dynamic system in this way include the desire for presentational simplicity and, most importantly, the desire for a useful interpretation of the system under investigation. A dynamic system is said to display hysteresis by an investigator who judges that the current state of the system is best understood in terms of its past. In such cases the natural description of the state of the system will include explicit reference to the past. This suggests that whether or not one characterizes a system as hysteretical depends not only on technical characteristics of the system but also on individual judgments about the adequacy of various descriptions to the understanding of the phenomenon under investigation. To illustrate this point, recall Elster's hysteretical relationship between basis and superstructure. Elster (1976) suggests that one might eliminate the appearance of hysteresis in the superstructure by summarizing in current culture c_t the influence of the past superstructure s_{t-1}. If $c_t = c(s_{t-1})$, we can introduce culture as a new state variable and write $s_t = s^2(b_t, c_t)$. Such algebraic manipulation does not yield a non-hysteretical system, however, *unless* one finds that the reformulation leads to the judgment that the superstructure is best understood without reference to its past.

Interest in hysteresis is an interest in the importance of the past for our understanding of the present. Applications pervade the social sciences. Hysteresis can be important in explaining the evolution of institutions, organizations, and technological systems. A classic example is the adoption of the QWERTY key

board, an example that suggests that standards for technological compatibility may not evolve efficiently. Current norms and institutional structures, which contribute to the feasible range of economic activity, cannot be understood without reference to the past. Random historical events can strongly influence the collusive success of oligopolies that can monitor each other only imperfectly, the locational commitments of firms and households in the presence of agglomeration externalities, and the behavioral rules of thumb adopted in circumstances of bounded rationality. Past consumption patterns are important influences on current and future consumption: habit formation is hysteresis in preferences. Current production levels depend on the historical paths of factor inputs, not just on current inputs. The trade balance may be permanently affected by a large, transitory real exchange rate shock if entry into foreign markets involves significant sunk costs. The social mobility of individuals may depend on the class history of previous generations. False trading (disequilibrium exchange) can influence equilibrium prices and quantities. The 'natural' rate of unemployment appears to depend on the history of unemployment. Hysteresis effects on human nature deriving from the history of capitalism may be crucial considerations for those who wish create social institutions that rely on altruism or feelings of community.

Hysteresis may even be relevant to questions of distributive justice, since justice may be best pursued through reference to past actions. From a natural rights perspective, the current distribution of wealth and income may be judged to be just if it arose without violating individual rights. Similarly, if the distribution of income and wealth should respond to merit, and if merit is seen as deriving from past actions, then judgments of justice will refer to past actions. To refer simply to current merit is possible but less informative.

In many of the examples above, the past is so persistent that different initial states generate divergent long run outcomes. David (1988) suggests that we can think of path dependent systems as those that are unable to sever their links with the past no matter how much time passes. In general accord with the current hysteresis literature, one may consider such path dependence in the context of globally stable systems. Every solution of a globally stable system converges, so path dependence in this context bespeaks multiple equilibria. Multiple equilibria are associated with the presence of null (unit) characteristic roots in linear systems of differential (difference) equations. In non-linear systems, multiple equilibria can be generated in a variety of ways. Many social scientists have reserved the term 'hysteresis' for situations displaying this path dependence of equilibrium outcomes. As David notes, the implications of such hysteresis for applied work in economics are radical: when the influence of the past persists strongly in the present, good applied economics will generally require good economic history. Hysteresis implies that a careful description of the past is crucial for understanding the present and predicting the future. In the presence of pervasive hysteresis, economics must become a truly historical science.

REFERENCES

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