



sure into chaos and fractals. He claims that there exist connections for unusual reasons. At one point he states that many of the measures are related because they "all are concerned with scaling." This seems a rather shaky piece of evidence to stand on.

We have a lot of evidence in this book and elsewhere that prices do not follow random walks. However, what remains unclear is just what process they are following. Few of the tests here have the power to distinguish between different types of stochastic processes, either linear, or nonlinear. We are still left wondering what process is appropriate for price movements. Peters emphasizes a confusing array of deterministic chaos, fractional Brownian motion, and nonlinear stochastic systems as potential candidates. While different versions of these may be good contenders it is still not clear how to sort out among them. More simulations need to be done to clearly demonstrate certain tests as pivotal in distinguishing these different hypotheses.

The book ends with some statements about the future which I certainly agree with. We need to better think out models for financial price movements that can account for interactions of agents operating at different time scales and with differing information. More appropriate models of risk need to be formed that can account for what people are concerned with in real markets. It may often be the large and sudden jumps that worry investors the most rather than the continuous wiggles over time. The amount of determinism and randomness involved in these large moves still remains a mystery. Stock return series remain some of the most studied time series around, but many of their secrets still remain hidden. Peters attempts to reveal some of these features, but we are still left with much to find out.

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REFERENCES

1. P. K. Clark, "A subordinated stochastic process model with finite variance for speculative prices," *Econometrica*, Vol. 41, 1973, pp. 135-155.
2. T. Bollerslev, R. F. Engle, and D. B. Nelson, "ARCH Models," in *Handbook of Econometrics*, Vol. 4, North-Holland, New York, forthcoming.
3. A. W. Lo and A. C. MacKinlay, "Stock prices do not follow random walks: evidence from a simple specification test," *Review of Financial Studies*, Vol. 1, 1988, pp. 41-66.
4. B. Efron, "Bootstrap methods: Another look at the jackknife," *The Annals of Statistics*, Vol. 7, 1979, pp. 1-26.
5. B. Efron and R. Tibshirani, *An introduction to the bootstrap*, Chapman and Hall, 1993.
6. A. W. Lo, "Long-term memory in stock market prices," *Econometrica*, Vol. 59, 1991, pp. 1279-1314.
7. B. W. Ambrose, E. W. Ancel, and M. D. Griffiths, "Fractal structure in the capital markets revisited," *Financial Analysts Journal*, 1993, pp. 73-77.
8. M. Loretan and P. C. B. Phillips, "Testing the covariance stationarity of heavy-tailed time series: An overview of the theory with some applications to several financial series," *Journal of Empirical Finance*, Vol. 2, 1994, pp. 211-248.



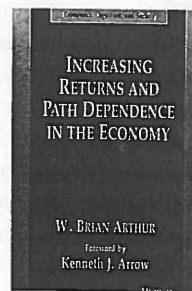
Remembrance of Things Past

Recent research in economic history and macroeconomic theory has experienced a remarkable confluence of paradigms over the last decade. These usually distinct fields of study have become united by the concept that history matters, that is, that particular realizations of the sample path of the economy's behavior can have permanent effects on an economy's behavior. Economic environments in which individual historical episodes can have such persistent consequences are, of course, far different from those in which a law of large numbers can be expected to prevail.

This class of "path-dependent" models has developed in the context of a wide variety of economic environments. In general, these environments have two characteristics in common. First, individual deci-

sions are mutually reinforcing in the sense that a particular choice of action by one economic agent is more probable when other agents make similar decisions—a characteristic often referred to as strategic complementarities. Second, individual agents act in a decentralized fashion, meaning that their choices are not mutually coordi-

nated either formally through contracts or informally through communication. This market incompleteness means that individual agents cannot fully compensate one another for the consequences of their actions. Together, these two characteristics imply that multiple configurations of individual decisions may exist, under each of which individual decisions are rational. Examples of economic situations in which these characteristics hold include 1) the choice of a



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technology standard such as DOS or UNIX when the desirability of an operating system depends upon how widespread is its use, 2) the location of technologically similar firms when transport costs and network externalities make it desirable for similar firms to cluster geographically, 3) the level of parental investment in offspring human capital across families in a common neighborhood when the payoffs of such investments depend on whether other families are also making them because of peer group effects, and 4) the level of aggregate production when individual firm production decisions influence others through demand spillovers.

Brian Arthur has been the pioneer in the theory of path-dependent economies, and his collection *Increasing Returns of Path Dependence in the Economy* brings together many of his writings for the first time. Arthur has developed a compelling set of models of path-dependent economies based upon two methodological insights. First, he has demonstrated the importance of increasing returns to scale in creating incentives for individual economic agents to behave similarly to one another. Loosely speaking, increasing returns may be said to characterize any environment in which two economic agents working in conjunction are more than twice as productive as either working in isolation. This idea has provided persuasive microeconomic foundations for the strategic complementarities that other researchers have merely assumed. Second, by embedding increasing returns in a dynamic framework, Arthur has developed several plausible economic environments in which individual decisions are not coordinated.

In working out a set of economic theories in which the limiting behavior of economies is not uniquely determined by the characteristics of the individual agents, depending as well on the initial conditions and/or stochastic shocks experienced by the economy, Arthur has also influenced the way in which aggregate economic outcomes

are conceptualized. By emphasizing the connection between complex cross-sectional interactions and aggregate dynamics, he has helped influence economic theory in the direction of treating aggregate economic behavior as an emergent characteristic of an evolving heterogeneous population of economic agents. This conceptualization has influenced theoretical work on many topics including the evolution of trading networks (Yannis Ioannides [1]); asset price fluctuations (William Brock [2]); neighborhood formation and inequality (Steven Durlauf [3]); and city evolution (Paul Krugman [4]). It has also informed important critiques of standard economic modeling methods (Alan Kirman [5]). In this respect, Arthur's work has been instrumental in placing complexity at the center of much current economic theorizing.

Taken as a whole, this beautifully written collection of essays represents one of the fundamental contributions to economic science in the last two decades. As a general survey of the main themes of Arthur's work, the essay "Positive Feedbacks in the Economy" provides a very clear statement of the powerful implications of increasing returns for economic dynamics at a level which can be understood by a layman; a more sophisticated version of these ideas which is suitable for a graduate-level reading list is contained in "Self-Reinforcing Mechanisms in Economics." The potential for path dependence to occur in interesting economic contexts is shown in several essays including the now classic "Competing Technologies, Increasing Returns, and Lock-In by Historical Small Events" as well as such papers as "Industry Location Patterns and the Importance of History" and "Urban Systems and Historical Path Dependence," which develop an economic theory of the Silicon Valley. Additional insights into the implications of increasing returns for price behavior are found in "Strategic Pricing in Markets with Increasing Returns," co-authored with Andrzej Ruszcaynski. Extensions of

the notions of strategic complementarities to learning are found in "Information Contagion," co-authored with David Lane, and "Path Dependence, Self-Reinforcement, and Human Learning." Much of the underlying mathematics of path dependence stems from "Strong Laws for a Class of Path-Dependent Stochastic Processes," co-authored with Yuri Ermoliev and Yuri Kaniovski, in which a wide variety of nonergodicity results are derived for generalizations of the Polya urn model; "Path-Dependent Processes and the Emergence of Macrostructure" provides a gentle introduction to this mathematics.

Finally, it is worth noting the introduction to the book, in which Brian Arthur recounts the difficulties he faced in getting his papers published, most notably the ground-breaking "Competing Technologies, Increasing Returns, and Lock-In by Historical Small Events." While it is always easy to criticize in hindsight, the subsequent influence of this paper and the other essays in this volume is a powerful indictment of the excessively conservative editorial policies of many economics journals in assessing research which deviates from the conventional modeling assumptions.

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REFERENCES

1. Y. Ioannides: Trading uncertainty and market structure. *Int. Econ. Rev.* 31:3, pp. 619-638.
2. W. Brock: Pathways to randomness in the economy: emergent nonlinearity and chaos in economics and finance. *Estudios Economicos* 8:1, pp. 3-55 and *Social Systems Research Institute Reprint #410*, Dept. of Economics, Univ. of Wisconsin at Madison, 1993.
3. S. Durlauf: A theory of persistent income inequality. Univ. of Wisconsin (mimeograph) and *J. Econ. Growth* (forthcoming).
4. P. Krugman: The self-organizing economy. Stanford University (unpublished manuscript), 1995.
5. A. Kirman: Whom or what does the representative agent represent? *J. Econ. Perspectives* 6:2, pp. 117-136.