Book Review

"The Current State of Research on Dynamic Economics"

A Review Article of: Giancarlo Gandolfo: *Economic Dynamics*, third edition

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Reading this completely revised and enlarged edition of Gandolfo's well known book provides pleasant flashbacks to my days as an aerospace engineer on the Apollo project (such engineers are now called "rocket scientists" by economists). Engineers have long been accustomed to having encyclopedic books available on engineering dynamics. For over a half century, the tools of continuous time and discrete time dynamics have been a fundamental part of the training of all engineers and physical scientists. Those tools have been so fundamental in engineering and science that there has been little controversy regarding their use; and which tools belonged in a graduate text book on engineering dynamics has been clear and beyond dispute for decades. Yet economists were stuck in comparative statics and general topology for so long that little consensus yet exists on just what an economist needs to know about economic dynamics. To this day dynamics remains a state of the art direction for research in economics.

1. Overview

Gandolfo's book is admirable for its encyclopedic nature and its absence of evident bias in the choice of emphasis or coverage. This book stands apart from the other books on economic dynamics in its open minded and scholarly coverage of a remarkably broad area of research on economic dynamics. Readers seeking a book that makes a strong case for a

particular "school of thought" on economic dynamics will not be happy with this book. This fact surely will disturb those potential readers who want a book that "takes a stand" on the position of any of the profession's clans. Which one is right? How about ARMA or ARCH processes, processes that are nonlinear in the mean, chaos, real business cycle theory, bifurcation, Keynesian economics....or even catastrophe theory? We economists have become accustomed to the idea that any book should advocate one or more of those approaches, or at least should dismiss, out of hand, a few of them. Gandolfo does not do so. In fact if there is any clear evidence of a bias in methodology in this book, it is the bias of a person who thinks like an engineer or physical scientist. If there is any evidence of the economist's methodological preferences, rather than the engineer's or physical scientist's current methodological preferences, the evidence is in the book's extensive treatment of linear dynamics, which dominate the first half of the book. But of course the book is written for economists, and those economists willing to go beyond the mathematics of the very distant past need only read on into the second half of Gandolfo's book..

Gandolfo's book is a book of dynamic tools with illustrations from many areas of economics, including areas that currently are having great influence on economic research and areas that have had little influence on economic research for years. In short, this book is what a reference book on economic dynamics should be. As a monograph supporting some form of advocacy, the book is not what it should be, but then that is not what the book is intended to be. Not only is the book valuable as an encyclopedic reference book for researchers, but is an excellent choice for a textbook on economic dynamics, since Gandolfo has managed to provide background in even some of the most advanced areas of dynamic economic research in a readable manner avoiding unnecessarily advanced notation. Hence the book remains broadly accessible without avoiding mention of many of the deepest areas of current research in economic dynamics.

The nature of the tools presented in the book are the tools of theory, rather than the tools of inference. Hence readers looking for references on generalized method of moments estimation of dynamic structural models, bispectral methods of testing for nonlinearity of time series, asymptotic statistical theory, Bayesian methods, or calibration approaches to comparing empirical properties of models will find little of interest in the book. However, there are some exceptions. The book does, for example, include some discussion of the literature on testing for chaos. However, this area of research is so turbulent, that almost anything that might be written is sure to be viewed as "old hat" a few months later. In fact, there has been a competition among tests for nonlinearity and chaos that has been under way for a few years, and the results are now in. Although those results were not available at the time that Gandolfo produced this revision of his book, those results now can be found in Barnett, Gallant, Hinich, Jungeilges, Kaplan, and Jensen (1996) But then by the time that this review article has been published, who knows what newer empirical twist will be available on that subject?

2. Detailed Comments

Judged on its own grounds, it is difficult to find anything to fault in this book. A glance through the table of contents and the index at the end of this book is enough to indicate to almost any serious economist that this is a book to buy. However, I have a few observations in that regard.

Back in my previous life as an engineer, my colleagues and I could do without Laplace transforms about as easily as we could do without multiplication. Yet I can't remember the time that I last saw a table of Laplace transforms in the office of an economist. I've wondered about this fact periodically, and I do not find an answer in Gandolfo's book.

Recursive discrete time models using Bellman's method are fundamental in many important areas of dynamic economics, especially in modern macroeconomics. While

dynamic programming and Bellman's work can be found laced into some parts of this book, a separate chapter on that subject would be a welcome addition to the book. After all, there are entire books that have been written on recursive discrete time dynamics in economics.

Gandolfo's treatment of continuous time methods is outstanding, and includes some areas of that research that are known only to leading edge specialists in the field. But again a regrouping of some of those methods into sections or chapters would have been useful to some readers. The following approaches are of such fundamental importance that separate sections, rather than interweaving into various sections, would have made reference easier for some readers: calculus of variations, Hamiltonian systems, Pontryagin's principle, transversality conditions, Inada conditions, sunspots, Strotz consistency, time inconsistency, correlated equilibria, and dynamic games. I do not wish to suggest that those topics are not covered in Gandolfo's book. Reference to the book's index indicates otherwise, and in fact a useful discussion of some of those topics is included in his section 22.1, with section 22.1.2 having the relevant title, "The Maximum Principle." But some readers may wonder why those influential topics and tools were interwoven into the book, while the following topics were given entire sections or subsections: catastrophe theory, the Shil'nikov scenario, Kalecki's business cycle theory, and synergetics.

Similarly in any discussion of nonlinear differential equation systems, the subject of existence of a solution and the use of the Lipschitzian is logically prior to consideration of solution methods. Hence serious consideration of existence merits a separate section. While Gandolfo does cover that subject, he does so in a footnote (on p. 430). A full section with the title "existence of solutions to nonlinear differential equations" would more suitably highlight the importance of the entirely nontrivial existence issue.

I do not wish to suggest that any of the topics included in the book should have been deleted from the book. In fact I find it refreshing and in some ways encouraging to see such

open minded coverage of topics that many economists would view as being somewhat "exotic." But then why shortchange some of the currently more influential areas of economic dynamics in terms of relative space allocation and section grouping?

Inclusion of separate sections on each of the topics I suggest above in continuous time and discrete time dynamics would surely increase the length of this book. Since the book already is 610 pages long, the price of this hardbound volume could become a problem for sales, if further dedicated sections were to be added. Perhaps there will be a fourth edition----available as a paperback---or online.

3. Chaos:

Gandolfo's book contains interesting discussion of nonlinear dynamics, chaos, and bifurcation theory in advanced sections near the end of the book. I am very much in favor of inclusion of those topics in this book. Yet recently there has been considerable criticism of those areas of research, as for example in Granger's (1994) review of Benhabib's book. I specifically mention that review, since it appeared in this journal.

I wish to suggest that it is unwise to take a strong opinion either pro or con in that area of research. Contrary to popular opinion within the profession, there have been no published tests of chaos *within the structure of the economic system*, and there is very little chance that any such tests will be available in this field for a very long time. Such tests are simply beyond the state of the art---far beyond the state of the art. Without the existence of any empirical evidence one way or the other, it seems inappropriate either to dismiss or embrace what I call the "five letter dirty word": chaos.

All of the published tests of chaos in economic data test for evidence of chaos in the data. If chaos is found, the test has no way of determining whether or not the source of the chaos is from within the structure of the economy or perhaps is from within the chaotic weather systems that surround the planet. Considering the fact that chaos is clearly evident in

many natural phenomena, and considering the fact that natural phenomena introduce shocks into the economy, the observation of chaotic behavior in some economic variables should be no surprise, but should give us no reason to believe that the economic system is chaotic, or is not chaotic.

To isolate the source of chaotic economic data to be within the economic system, a model of the economy must be constructed. The null hypothesis that then must be tested is the hypothesis that the parameters of the model are within the subset of the parameter space that supports the chaotic bifurcation regime of the dynamical system. But mathematicians do not have the ability to find and characterize that subset, when more than three parameters exist. Hence with any usable model of any economy, the set that defines the null hypothesis cannot be located with current mathematical tools. No one can test a null hypothesis that cannot be located and defined. If this is not sufficiently discouraging, consider what would happen if at some time in the future mathematicians were able to solve for that set for a reasonable economic model. The set would be a Cantor set. Nothing is known about testing a hypothesis defined in terms of a Cantor set. The likelihood function would be filled with singularities. The regularity conditions needed to apply existing inference procedures would be violated.

Since we cannot test the hypothesis, we may instead wish to consider whether or not chaos is plausible on philosophical ground. On that basis, the question would be whether the economy should be viewed as having evolved naturally, as in the natural sciences, or was the product of intentional human design by economic "engineers." Systems intentionally designed to be stable by engineers are stable and not chaotic, if designed optimally. Nature was not designed by human beings, and is chaotic. The weather will never converge to a steady state. Which view is most appropriate to understanding the dynamics of economies is not clear.

In short, we do not have the slightest idea of whether or not the economy exhibits chaotic nonlinear dynamics, and hence we are not justified in excluding the possibility.

4. Conclusion

Buy the book. Also get your library to buy it. Then send letters to Gandolfo asking when to expect the fourth completely revised and enlarged edition.

REFERENCES:

Barnett, William A., A. Ronald Gallant, Melvin J. Hinich, Jochen Jungeilges, Daniel Kaplan, and Mark Jensen (1996), "A Single-Blind Controlled Competition among Tests for Nonlinearity and Chaos," *Journal of Econometrics*, forthcoming.

Clive W. J. Granger (1994), "Is Chaotic Economic Theory Relevant for Economics" A Review Article of: Jess Benhabib: Cycles and Chaos in Economic Equilibrium," *Journal of International and Comparative Economics* 3, 139-145.