

Furthering Our Understanding: How Does Chaos Theory Relate to Economics? November 2006

There is an often quoted saying about chaos theory that goes: “A butterfly flaps its wings in Tokyo and there is a hurricane in New York.” This is fine for physics and meteorology, but what happens if Mr. Chou buys stocks in Tokyo and the market crashes in New York? Chaos theory is still an emerging field in many different disciplines, including economics, and this paper will look at what applications and implications it has for economic theory. The paper will begin with an overview of chaos theory itself, move to the variety of applications within economics, and finish with the implications for the field of economics and a fanciful comparison of chaos theory to previous economic ideas. Overall, it should be apparent that chaos theory may assist with predicting economic systems and will undoubtedly open pathways to new economic research, but also that it has shortcomings and flaws. Chaos theory holds great promise for economics if approached correctly: as a field with burgeoning applications as opposed to a silver bullet for the problems of modern economics.

A Brief Overview of Chaos

The idea of chaos, and order within chaos, has fascinated humans since the beginnings of civilization. The ancient Babylonians believed the world was birthed from primordial chaos, leading to an epic battle in which Marduk, the god of light, slew the monsters of chaos.¹ For millennia, human science and ingenuity have continued this struggle against the ideas of chaos, striving to make sense of the world and determined to offer a rational explanation for the patterns of human existence. This effort to order the world reached its climax during the Enlightenment thought of the 17th century and the intellectual ideas of the following two centuries. The rational, mechanistic worldview manufactured by enlightenment thinkers can be seen across the fields of human achievement, from the physical sciences to economics; the world came to be seen as a well running machine following established natural laws, which it was the prerogative of science to discover. For economics in particular the common goals and efforts of people allowed the world to be contained within a well specified model.² Alfred Marshall, the British economist, is well known for contributing to this modern model of economics—taught everywhere today as standard microeconomics.

¹ Joseph L. Spradley, *Visions that Shaped the Universe* (McGraw-Hill, 1994) 15.

² James Halteman, *The Clashing Worlds of Economics and Faith* (Scottsdale: Herald Press, 1995) 21. Halteman calls this view the “modern” view as opposed to the Enlightenment view, but the concept remains the same. The “well specified model” is represented in the book by an image of a human looking down from above into the predictable machine of the world, endeavoring to understand the laws governing it.

It is into this world of perfectly explained Newtonian physics, standard algebra, and neoclassical microeconomics that chaos theory has redrawn the battle line between order and chaos over the past half century. The New Oxford American Dictionary defines chaos theory as “the branch of mathematics that deals with complex systems whose behavior is highly sensitive to slight changes in conditions, so that small alterations can give rise to strikingly great consequences.”³ The field began in the early 1960s with the work of Edward Lorenz, a meteorologist studying the patterns of weather in a simple system. Two important observations came out of Lorenz’s work that, when taken together, provide a good overview of the basics of chaos theory.⁴

First noted by Lorenz was the Butterfly Effect described in the introduction to this paper, known to the proponents of chaos as “sensitive dependence on initial conditions.” Coming from the viewpoint of Enlightenment mechanism, slight changes in the starting point of a system should yield a slightly different system in the long run. Lorenz found, however, that within a short period of time two simulations that were all but identical at the outset would become unrecognizably disparate. Simply put, a simple system that should have been easily predictable would be drastically different if variables were changed in the slightest way.

This would have been only “a piece of very bad news” had Lorenz not anticipated that chaos was more than pure randomness, but in reality a fine structure “masquerading as randomness”.⁵ He proceeded to show that a sense of order really did exist within chaos: the system stayed within certain bounds, but never settled down into a pattern—looping infinitely but never repeating. His system had only three variables which, when mapped on a three dimensional plot, created a haunting figure known as the Lorenz Attractor. The idea is that a chaotic system will reveal order within its disorder but will never repeat itself. If ever all the variables in a system reach a point they have all been at before, then the system will loop infinitely around that point like a sound track on repeat—becoming perfectly predictable and therefore not chaos.

From this humble beginning, chaos theory has expanded to offer a new and competing explanation for the interactions of the world around us. What used to be ignored as unsolvable equations or errant data is now often considered as a beginning for chaos research. The field is highly mathematical, dealing with non-linear equations that produce chaotic results; it reveals

³ “Chaos theory,” *New Oxford American Dictionary*, (Oxford University Press, 2005).

⁴ James Gleick, *Chaos: Making a New Science* (New York: Viking, 1987) 11-31. The following two observations are a summary of the first chapter of the book.

⁵ Gleick 22.

order within infinite complexity in systems spanning all scales of size. The next section of the paper will look at the point of contact between these ideas of chaos and the field of economics.

Economic Chaos

Compared to other fields such as mathematics, physics, biology, and meteorology, the application of chaos theory to economics is, in many ways, still in its infancy. The synthesis of supply and demand provided by Marshall and the other neoclassical economists has left a legacy of normal, linear economics. The major viewpoint within economics is that economic systems will settle into a stable steady state, varying only with exogenous shocks that force the system to recalibrate.⁶ This does not mean, however, that ideas are not forthcoming; on the contrary, there have been numerous attempts to synthesize the two fields. This section will look at a few of these, from the early days of chaos theory to modern applications, and then examine reactions and objections to the synthesis.

About the time that Lorenz was pioneering the beginnings of chaos theory, Benoit Mandelbrot was observing chaotic tendencies within economic data.⁷ In this case, it was two different sets of data—income distribution and cotton prices—that refused to fit into the stereotypical bell-shaped curve of rational science. Yet a strange order pervaded the data, as apparently random fluctuations produced identical patterns at the daily and monthly level. In fact, both data sets were displaying characteristics of what later came to be known as Mandelbrot sets, with ordered patterns repeating themselves across all scales. In effect, size was becoming irrelevant and order was appearing within seemingly irrational data. Though Mandelbrot was not an economist, he saw the possibility for the application of chaos theory to economic data. This was just a small-scale sidetracking into economics by a brilliant chaos theorist, but many others have carried chaos into economics in far more complex ways.

In the International Library of Critical Writings in Economics' compilation of articles over chaos theory, W. Davis Dechert breaks down the applications of chaos theory in economics by dividing it into three approaches: the "methodology of nonlinear dynamics" in economic theory, the "modelling [sic] of economic dynamics", and statistical tests for evidence of chaos within economic data.⁸ Each approach represents a different means of applying chaos theory to economics and the three together provide a good overview of the field.

⁶ Michele Boldrin, "The Impact of Chaos on Economic Theory," in *The Impact of Chaos on Science and Society*, eds. Celso Grebogi and James A. Yorke (Tokyo: United Nations UP, 1997) 275.

⁷ Gleick 83.

⁸ W. Davis Dechert, introduction, *Chaos in Economics: Methods, Models, and Evidence*, ed. W. Davis Dechert (Cheltenham: Edward Elgar Publishing Ltd., 1996) xiii.

The “methodology of nonlinear dynamics,” the first approach, focuses on the methods by which chaotic tendencies can be detected within economic systems. William Brock, a prominent proponent of research into chaos within economic systems, has been instrumental in this area, contributing such ideas as the Brock, Dechert, and Scheinkman Test for detecting statistical nonlinearities. In his article “Pathways to Randomness in the Economy: Emergent Nonlinearity and Chaos in Economics and Finance,” Brock presents methods for approaching chaos theory within economic systems.⁹ First Brock approaches the economic data by using the Lyapunov exponent, an indicator of chaos within a system. Chaos theory states that a strange attractor—“an equation or fractal set representing a complex pattern of behavior in a chaotic system”¹⁰—must have at least one Lyapunov positive exponent, indicating properties within a system tending towards instability.¹¹ Brock uses the Lyapunov exponent to test for nonlinearity and chaos in Independent and Identically Distributed processes within economic functions and equations. The second method is the application of ideas from particle physics to economic research. Brock observes that the conventional models of asset pricing do not provide for dramatic effects produced by slight changes in the system. To address this concept using chaos theory, Brock draws on “the probability structure of interacting particles systems” along with discrete choice theory and theoretical arguments to generate an economic method with which we can approach chaos.¹² Though different, both methods demonstrate the possibility of economic research into chaos.

Dechert’s second approach focuses on economic modeling. Since the neoclassical era, there has been great emphasis within the field of economics on producing working models of economic systems—from the simple model of supply and demand to the more complicated monopoly and oligopoly models to macroeconomic theories such as the IS-LM model. All these models, however, embody the static equilibrium viewpoint of mainstream economics. If chaos theory is to make a big impact, it must produce manageable models to anticipate the consequences of chaos on systems.

An example of such a model can be seen in Jean-Paul Chavas and Matthew Holt’s paper examining supply and demand for milk in the dairy industry, in which they rethink the simple

⁹ William A. Brock, “Pathways to Randomness in the Economy: Emergent Nonlinearity and Chaos in Economics and Finance,” in *Chaos in Economics: Methods, Models, and Evidence*, ed. W. Davis Dechert (Cheltenham: Edward Elgar Publishing Ltd., 1996) 3-55.

¹⁰ “Strange attractor,” *New Oxford American Dictionary*, (Oxford University Press, 2005).

¹¹ Gleick 253.

¹² Brock 16.

supply and demand model within the context of chaos theory.¹³ The idea behind Chavas and Holt's model is that fluctuations within a simple supply and demand system are not necessarily exogenous shocks, but may display "a kind of dynamic order without periodicity."¹⁴ In this case, the model returned two results: one relating to elasticity and one to price floors. The demand for milk within the dairy economy was assumed to be somewhat inelastic at the level of the individual farm, for which Chavas and Holt's model indicated that the more inelastic the demand, the more chaotic the system became. Price floors also produced a change in the system: as price floors were increased, the chaos of the system "gave way to limit cycles". This indicated that chaotic tendencies within a free market system can be dampened by external intervention. Though simple, the model suggests the possibility of attributing fluctuations within economic variables to chaos rather than to noise caused by exogenous shocks, which has been the traditional position.

Statistical tests for evidence, the third approach outlined by Dechert, is the most controversial. The first two approaches attempt to produce methods and models to address chaos within economic systems, while this approach attempts to prove the existence of such chaos from the data. Economic data can be difficult to examine for evidence of chaos due to problems associated from reducing it to mean stationary time series, the influence of outside institutions such as politics and technology, and the quality and uniformity of the data.¹⁵ While this may make it difficult to search for chaos within systems, it is by no means impossible.

Market records are a favored source of data in the search for chaos within economics. Steven Blank did just this sort of analysis with data from the S&P 500 and the soybean futures market, examining it for the existence of chaotic tendencies.¹⁶ Blank lays out three steps for a general test for chaos: calculating a correlation dimension for the data, examining the residual instead of line fitting the data, and examining the Lyapunov exponents. For the study cited above, the results for both S&P 500 and soybean futures were intriguingly similar: both the correlation tests and the Lyapunov exponents indicated the presence of nonlinear trends within the data. This implied some level of chaos within the markets that generated the data. However, as Blank notes, there is no test to determine the statistical significance of Lyapunov exponents and other indicators, and thus the results are "necessary, but not sufficient

¹³ Jean-Paul Chavas and Matthew T. Holt, "Market Instability and Nonlinear Dynamics," in *Chaos in Economics: Methods, Models, and Evidence*, ed. W. Davis Dechert (Cheltenham: Edward Elgar Publishing Ltd., 1996) 322-329.

¹⁴ Chavas 323.

¹⁵ Boldrin 278-279.

¹⁶ Steven C. Blank, "'Chaos' in Futures Markets? A Nonlinear Dynamical Analysis," in *Chaos in Economics: Methods, Models, and Evidence*, ed. W. Davis Dechert (Cheltenham: Edward Elgar Publishing Ltd., 1996) 479-496.

conditions to prove the existence of deterministic chaos.”¹⁷ Much similar data has been examined, some much more complicated, and the results, though often inconclusive as to the extent to which chaos affects economic systems, are interesting enough to encourage further research.

Implications of Chaos

In reviewing Dechert’s three approaches to chaos theory, it is apparent that there are questions regarding the effectiveness and applicability of chaos theory to economics. In addition to the problems associated with the data, as covered above, there is the problem of the high number of variables and complexities within economic systems and the idea that there are basic economic forces that work against “complicated dynamic patterns.”¹⁸ However, despite difficult approaches and sometimes inconclusive results, chaos theory has potential within the economics of the future. As Brock notes, “just because evidence for chaos in time series data is weak does not mean that chaos is not a useful lens through which to view economic activity.”¹⁹ This section will look briefly at the implications of chaos theory for the economics of the future, both for prediction and for providing a new lens through which to view the economic world.

There is much hope that chaos theory will be able to predict fluctuations and discrepancies that were previously considered to be simply random noise or discrepancies created by exogenous shocks. This possibility can be seen in all three of the approaches to chaos outlined in the previous section. In one sense, this desire to discover the source of fluctuations is the continuation of the quest of the Enlightenment model to order the world; only this time it is ordering the world with chaos—discovering coherent patterns within the static of human economic activity.

With the advent of the modern era and the vast amounts of economic activity, accompanied with equally large amounts of data, the need for new economic models is keenly felt. Chaos theory will contribute to these methods and models in large ways as economic systems yield themselves to more detailed study. Even skeptics of chaos within economics believe that it will bring about new insights into market fluctuations.²⁰ One major area of application will be the stock and futures markets. As evidenced in the article by Steven Blank

¹⁷ Blank 494.

¹⁸ Boldrin 279-281.

¹⁹ Brock 6.

²⁰ Boldrin 294.

cited above, there is already work being done in this area. Blake LeBaron points out that while chaos research may not directly affect the trader in his daily activities, it will be taken into mind when creating models for future market patterns.²¹ The same concept applies across the fields of economic research: chaos may help explain fluctuations in order to generate more accurate models.

The second implication of chaos is not the acceptance of chaos theory as a valid explanation for economic systems, but rather the opening of economic thought to new ideas. In many ways this expanding of the horizons of economic research is much more important than the acceptance of any particular theory. Chaos theory has already brought nonlinear analysis forward as a possibility for many economists and will continue to drive new methods in the future.²² As Brock notes, chaos theory has not been important in other sciences simply because of what it describes, but because “it is suggestive of pathways to complex dynamics” within the fields.²³

Responses to Chaos

So what are we to make of the idea of chaos within economics? Since the beginnings of modern economics during the Enlightenment, the field has changed immensely. What would those who have gone before think of the push of chaos into economics? This final section will indulge in a small use of improbable contrasts in an attempt to put chaos theory into a proper context within economics as a whole.

In the introduction to chaos earlier in this paper, the idea of chaos was presented in opposition to the neoclassical viewpoint of structured, stable economic systems. But in other ways, neoclassical economics and chaos theory are intrinsically related. The idea of market fluctuations, which chaos often looks at, depends on the theory of markets as developed by the neoclassicists. The research by Chavas and Holt into the dairy market accepted the premises of a supply and demand system, but looked for chaotic fluctuations within the system. Without a structure to build upon, chaos theory would have no data to analyze.

In addition, both neoclassical economics and chaos theory place an emphasis on mathematical analysis, though standard microeconomics is generally linear in nature, compared to nonlinear chaos. But linear or nonlinear, the views of Alfred Marshall, key thinker of the

²¹ Blake LeBaron, “Chaos and Nonlinear Forecastability in Economics and Finance,” *Philosophical Transitions: Physical Sciences and Engineering* 348 (1994): 400.

²² Boldrin 293.

²³ Brock 9.

neoclassical era, concerning mathematics are worth bearing in mind. Marshall understood mathematics as a wonderful tool for economic research; he also understood that it must be tempered by practical explanations. Marshall believed that if an economist could not demonstrate his mathematical conclusions using examples and plain language, then the conclusions were useless.²⁴ Granted, it may be slightly more difficult to represent the extremely mathematical ideas of chaos in plain language, but the point remains that economics is a science of human behavior and if the language of economics becomes too mathematical and inhuman, then the field has forsaken its roots.

This idea of economics as a science of human behavior leads to another view which may be contrasted with chaos theory. Traditionally, the rational behavior model has dictated the development of economic theories. Though humans are undoubtedly not entirely rational when it comes to decisions, the model has provided the best predictions and is therefore widely accepted. Yet there remain those decisions by humans which defy normal rational thought. Perhaps these contribute to the fluctuations which chaos theory may aid in predicting. On the other hand, economists that have focused on the shortcomings of rational thought might entirely disagree with chaos theory. The impersonal, mathematical focus of the field may be too far removed from humanity to convince some of its validity.

To illustrate the point, it may be instructive to look at the views of Adam Smith concerning human motivations. Though Smith is often considered to have laid the basis for rational thought as an economic idea, his beliefs were somewhat more complicated when it came to the motives behind our actions, as seen in his *Theory of Moral Sentiments*. Our rational actions, according to Smith, are derived from more complicated filters and causes, such as sympathy and, in the end, a supernatural overseer who guides the world.²⁵ Chaos theory, with its inherent fluctuations accepted as simply the natural order of a chaotic system, would seem contrary to this; what can such an impersonal explanation of an economic system mean to us as humans operating within the system? Yet perhaps this chaos can be taken a different way: as evidence of an even more complicated design that points to motives such as Smith's filters. It is worth remembering, as Smith did, that there is more to humans and their actions than simply the movements of the economic market.

Chaos, if it exists, cannot be stopped. Much as we as economists may fancy ourselves modern warriors in the battle to bring order to the world, chaos may explain many areas that have not been conquered despite all our economic models. The field of chaos theory is

²⁴ Stanley L. Brue and Randy R. Grant, *The Evolution of Economic Thought* (Mason: Thomson South-Western, 2007) 276.

²⁵ Brue 65.

expanding, and though a theory that explains economics completely in terms of chaos is extremely unlikely, the field will continue to produce new insights for years to come. Economics must learn to accept chaos, as it accepted the ideas of Marshall and the neoclassicists and of Smith before that. Through continual exploration of new fields, economics will become more rounded and able to deal with issues raised by modern systems. Chaos theory is intriguing and promising, offering infinite complexity along with simple order, much like human life. Let us hope that research into the realm of economic chaos theory continues.