Cycles and Evolution in Ecology and Economics

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Both ecological and economic systems are characterized by dynamic fluctuations of cyclical character, even if irregular. Over time these cyclical patterns evolve as the systems change their character. At certain critical points this can occur discontinuously. This paper argues that such saltational leaps are likely to be preceded either by a reduction in the variability or an increase in the variability of the system prior to the leap, depending on the point in the cycle and the nature of the leap.

I. Introduction

Among the topics discussed in Khalil (1992) are the questions of the nature of the formation of economic organization and structure and the nature of the economic evolutionary process. The former are seen as arising from the self-organizing behavior of out-of-equilibrium dissipative structures as argued by Nicolis and Prigogine (1977). He argues that cycles naturally arise out of such defined structures within economics and that these may be chaotic.

In another section of the paper Khalil discusses the question of gradualistic versus punctuated evolution in the context of technological change and Schumpeterian dynamics (Schumpeter, 1911). He argues that both occur with the process and routine changes occurring in a continuous manner while underpinning frameworks change discontinuously as a higher order process.

Drawing on my previous work (Rosser, 1990, 1991, 1992, 1993; Rosser and Rosser, 1993) I hope to draw these two strands of argument together in a unified framework and extend it in a way as yet unargued previously. This extended and unified framework will draw on the work of Holling (1973, 1986) on cyclical dynamics in ecosystems and the problem of the stability-resiliency tradeoff in such a framework. But it will extend Holling's work by identifying alternative circumstances under which discontinuous (saltationalist) evolutionary changes will occur and noting the parallel in economic cycles and structural transformations. At one point in the cycle a discontinuous leap is more likely to be preceded by a reduction in volatility whereas at a different point just the opposite will take place.

II. The Holling Model and its Economic Counterpart

C.S. Holling (1986) has presented a general model of the cyclical behavior of terrestrial ecosystems. This has come to be known as the "4-box" model. A given ecosystem can be characterized by its combinations of stored energy (capital) and degree of internal connectedness of organization. In the first stage or box the system is in a state of both low stored energy and low organization. It engages in increasing both and experiences rapid growth as new species colonize a freshly disturbed area.

The second stage is a period of conservation during which a gradual but balanced growth occurs. This leads to an ever greater interconnectedness of the system that can culminate in a "climax" form. Such a system reflects Holling's tradeoff in that it is very stable, a less-and-less moving equilibrium, which increasingly lacks resilience however. It is susceptible to an exogenous shock such as a fire or a storm or the introduction of a pest species.

This event causes a collapse of the system called a release because there is a great release of the stored energy (capital). This is the third stage Holling also labels "creative destruction" consciously after Schumpeter. As the release proceeds, interconnectedness declines also. This leads to the fourth stage in which there is a reorganization as the energy level increases and soil processes and nutrients prepare for the next round of exploitation, at the beginning of which there is a drop in energy levels before the takeoff begins again.

This 4-box cycle has an approximate correlate in the economic cycle. This can be seen by
comparing the conservation stage with the peak of a business cycle and the reorganization phase with the trough of the cycle. Of course the analogy is imperfect, especially in that during a business cycle the trough includes a reduced state of the capital stock whereas the capital stock is quite high during the equivalent reorganization in an ecosystemic cycle.

III. Dynamics of Discontinuity
So far we have seen one discontinuous event, the collapse of the climax ecosystem that has its equivalent in the generally sharper decline in output during a recession than the rate of growth that occurs during an upswing in growth (Brock and Sayers, 1988, have documented such business cycle asymmetry). However Holling argues that between the reorganization and the return of exploitation, essentially the bottom of the cycle, there is the possibility of something much more dramatic happening. The system can make a discontinuous leap to a completely different thermodynamic branch (Kay, 1989) and grow in a completely different form depending possibly on the initial invader species that initiate the takeoff into exploitation and renewed growth. Thus a former pine forest, burned down in a forest fire or wiped out by a pest, might very suddenly turn into a deciduous forest.

A similar process can happen in economic systems. Thus Schumpeter (1938) argued that it is the down phase of a long wave that brings forth the discontinuous technological change that eventually “creatively destroys” the old system and replaces it with something qualitatively different, not merely quantitatively so.

We note that a qualitative change at this stage involves a disequilibrium situation, quite likely involving enhanced oscillations in percentage terms. This is exactly the scenario of the “self-organization” situation. Indeed chaotic dynamics may well be involved out of which comes a systemic transformation.

A business cycle model that exhibits chaotic dynamics near turning points has been developed by Puu (1990, 1993). Such a model has been used by Rossler and Rossler (1993) in a long wave context to explain systemic transformation in the context of socialist systems switching to capitalism. Indeed the process of such transformation seems to entail a large amount of disorder.

IV. Structural Evolution
We have seen that at the bottom of the cycle is the possibility for a chaotically induced thermodynamic leap to a different kind of system, a Schumpeterian burst of saltational evolution. But now we must recognize that at the point of the collapse a structural transformation can occur also. This is the point of climax which is preceded by a reduction of oscillations. Indeed this would appear to be the scenario of the transition from socialism to capitalism, a rigidification of the old system occurring before it collapsed into a chaotic transition.

But here we can have an even more important event. Not only can there be the collapse or decline of the old system, but this collapse or decline can trigger related collapses or declines at lower or higher levels. A higher level triggering a lower level collapse is fairly trivial. Higher levels tend to serve as constraints on lower levels thus a discontinuous change at a higher level almost automatically triggers one at the lower level. If the forest burns down, so do the leaves. If the macroeconomy sours then so does the microeconomy.

What is less obvious but more dramatic is that the collapse of a lower level component or subsystem can concatenate upward to a higher level. Thus a leaf blight can destroy the forest. The collapse of a single bank can bring down a whole financial system. Here we have a more serious version of the lack of resilience phenomenon. Rigidification can precede larger scale upheaval and collapse. But the outcome may be a higher level reorganization and synthesis.

Finally we note that such an event can be preceded by a long period of being on the edge of a chaotic state. Thus Kauffman and Johnsen (1991) have shown that systems actually tend to move to the edges of chaotic states and that evolution is most likely to occur in such transitional zones. This tendency of systems to seek out the edge of chaos was probably first recognized by Alfred Lotka (1925). In Lotka’s case he saw this occurring not only with ecological systems but most especially with the human mind which he saw as seeking out bifurcation states. Systems in such poised states are subject to “avalanches” in which large-scale and discontinuities can occur.

V. Summary and Conclusion
Cyclical 4-box ecological or economic systems are most likely to experience abrupt evolutionary events either at their peak or at their trough. Discontinuities at the reorganizational trough are likely to be accompanied by chaotic dynamics that reflect the self-organizational, out-of-
equilibrium phase transitions that are involved. Discontinuities during the collapse from the peak are preceded by a rigidification and loss of resiliency. In certain cases these reflect a skirting at the edge of chaos. During the collapse the system can cross a higher order bifurcation point and generate a higher order discontinuous evolutionary transformation.

References


——— and Marina Vcherashnaya Rosser, 1993,