version: Monday, 03 June 2002

Chreods, path-dependence and evolution: chance and necessity in economic development (simulation study)

Witold Kwasnicki
Institute of Economic Sciences
Wroclaw University
e-mail: kwasnicki@ci.pwr.wroc.pl
http:/www.prawo.uni.wroc.pl/~kwasnicki

The presentation starts from short description of path-dependence concept and presentation of biological ideas of contingency and chreodic development. In the next section a description of evolutionary model of industrial dynamics is shortly described. In the final section a review of some results of simulation of the model is presented. The simulation is focused on presentation of the model's properties related to idea of path-dependence and chreodic development. In this lecture a selection of simulation results confirming the ideas of path dependence and canalised pathway of change (chreods) are presented. As we will see, to observe that phenomena it is not necessary to postulate any new mechanisms of development beside the well know Darwinian, natural mechanisms of generation of novelties (inventions, genotypes) and selection.

Path dependence, increasing return and lock-in

Path dependence emerged as an alternative perspective for economics in 1980s mainly due to publications of Paul David (e.g., 1985, 1995, 2001) and Brian Arthur(e.g., 1989, 1990, 1994, 1996). After almost 20 years of discussion a literature on path dependence has grown enormously. The idea has proponents but also critics (to mention only two names Stan Liebowitz Steve Margolis (e.g., 1994, 1995, 1996)[1]). Brian Arthur, distinguishes between "conventional economics," which largely avoids increasing returns or path dependence, and the "new" "positive feedback economics," which embraces them (Arthur, 1990:99). The idea of path dependence is closely related to such research propositions as "history matters", increasing return (or positive feedback) and lock-in.

Brian Arthur's (1989) consideration of path dependence is couched in terms of "lock-in by historical events." In his examples of the workings of positive-feedback models he finds that path inefficiency is possible where there are increasing returns. Ulrich Witt (1997) proposes alternative concept of 'critical masses' to describe industrial phenomena under network externalities.

[1] some publications of those authors are available at:
W. Brian Arthur - http://www.santafe.edu/arthur/
Paul David http://www.economics.ox.ac.uk/People/Members/DavidPA.htm
Stan Liebowitz http://www.utdallas.edu/~liebowit/

Institutional path dependence exists because of the network externalities, economies of scope, and complementarities that exist with a given institutional matrix. In everyday language the individuals and organisations with bargaining power as a result of the institutional framework have a crucial stake in perpetuating the system.

It seems that the ongoing discussion between proponents and critics of path-dependency caused Paul David to presents more elastic opinion contrary to Brian Arthur's stiffening position.

Paul David relates the concept of path dependence to non-ergodic systems in which the probability of a future event is influenced, if not determined, by previous experiences. It is also said that such systems are able to learn. *"Path dependence* ...., refers to a dynamic property of allocative processes. It may be defined either with regard to the relationship between the process dynamics and the outcome(s) to which it converges, or the limiting probability distribution of the stochastic processes under consideration." (David, 2001). In the same publication David proposes two definitions of path dependence, namely a negative one: "*Processes that are non-ergodic, and thus unable to shake free of their history, are said to yield path dependent outcomes*", and a positive one: "*A path dependent stochastic process is one whose asymptotic distribution evolves as a consequence (function of) the process own history.*"

This second definition describes processes with "*a multiplicity* of asymptotic distributions" and can be viewed as *branching processes*, "where the prevailing probabilities of transition among states are functions of the sequence of past transient states that the system has visited". (David, 2001).

In Brian Arthur's terms (Arthur, 1989) such systems can be 'locked-in', by which he understand a possibility of the system to enter into a trapping region, that is the basin of attraction that surrounds a locally (or globally) stable equilibrium. When a dynamic economic system enters such a region, it cannot escape except through the intervention of some external force, or shock, that alters its configuration or transforms the underlying structural relationships among the agents. Path dependent systems – which have a multiplicity of possible equilibria among which event-contingent selections can occur – may thus become locked in to attractors that are optimal, or that are jest as good as any others in the feasible set, or that take paths leading to places everyone would wish to have been able to avoid, once they have arrived there. (David, 2001).

The essence of Arthur's argument is that people get "locked-in" to the inferior standard. A critical mass of people adopts the standard thereby making the related goods cheaper (or more valuable) and thereby attracting more people to adopt the standard. In other words, a *feedback effect*. For example, as more people acquire DOS/WINDOWS computers, more software will be written for computers running this standard thereby making DOS/WINDOWS computers cheaper and more attractive for potential users. And so on.

Path dependence has since become linked to a cluster of theories said to describe the tendency of high-tech markets to encourage monopolies that may not necessarily offer the best technology. The standard examples of path-dependence are QWERTY story (as an inferior alternative to Dvorak keyboard), the VHS-Beta story, DOS computers vs. Apple's ones.

Brian Arthur defends his position in „The PreText interview"[2] where he answers to path-dependence critics. He says there that increasing returns are a form of positive feedback and it's "a body of economics that's exactly parallel to diminishing returns in neoclassical economics. It's the twin concept." While diminishing returns dominates 'classical economies', increasing return dominates in high-tech industries. Development process "grooves-in a path".

[2] see http://www.pretext.com/may98/columns/intview.htm.

He points out analogy to water flowing: "If rain falls on top of a sandy mountain, pretty soon it'll groove a pathway down the mountain and small events at the start will determine the topography and what rivers eventually form. It's important to note that the outcome is not completely determined by what's best. The outcome is partly determined by who gains what advantage when."

To the question: "Is the theory of increasing returns still controversial?", he promptly answers: "Absolutely not. This is now completely taken for granted in Silicon Valley."

While some writers do use path dependence simply to mean that history matters, many are explicitly concerned with efficiency problem.

Brian Arthur's writings on path dependence, as well as many other writings in this field (e.g., Katz and Shapiro 1986, Farrell and Saloner 1986) share certain elements. Most of them incorporate some version of increasing returns, which in this context may result from the usual economies of scale in the firm or from network effects. These increasing-returns economies often give rise to existence of multiple equilibria.

The literature of path dependence, both theoretical and empirical, contains a number of claims that path dependent processes lead us to inefficiencies, even for products sold in open markets. Brian Arthur cites as examples of this inefficiency the QWERTY typewriter keyboard (1989), the internal combustion engine (1989), and the VHS videorecorder (1990). Paul David (1985) tells the story of the QWERTY keyboard as a clear example of market failure. Paul Krugman's Peddling Prosperity contains an entire chapter called "The Economics of QWERTY, where he concludes, "In QWERTY worlds, markets cannot be trusted." (1994)

Liebowitz and Margolis (1998, 1998a) point out that there has identified two types of network effects: direct network effects (defined as those generated through a direct physical effect of the number of purchasers on the value of a product (e.g. fax machines)) and indirect network effects (i.e., "market mediated effects" such as cases where complementary goods (e.g. toner cartridges) are more readily available or lower in price as the number of users of a good (printers) increases). They agree that increasing returns are present in economic processes, but while economists have accepted the possibility of increasing returns, "they have generally judged that except in fairly rare instances, the economy operates in a range of decreasing returns" (Liebowitz, Margolis, 1998a). They agree that the "confluence of network effects, increasing returns, and market outcomes may be spurious. Although many technologies have tended to evolve into single formats (e.g. home-use VCRs are almost all of the VHS variety) some portion of these may actually have evolved for reasons having little to do with either network effects *or* increasing returns. We should not be surprised to find that where there are differences in the performance of various standards, one may prevail over the others simply because it is better suited to the market." (*ibid*)

Chreods and contingency

It seems that there is possible to find in biology, physics and mathematics similar concept to of path-dependency as presented in economics. In physics and mathematics the related ideas come from chaos theory. One potential of the non-linear models of chaos theory is sensitive dependence on initial conditions: determination, and perhaps lock-in, by small, insignificant events. In biology, the related idea is called contingency – the irreversible character of natural selection. Scientific popularization (Gleick, 1987, Gould, 1991) have moved these ideas into the public view.

Mokyr (1991) discusses the connection between biological contingency and path dependence in economics, presenting instances that appear ex post to be mistakes, instances of path dependence.

Contrary to contingency the idea of necessary path (or chreod) is not well known to economists. The idea was proposed over 50 years ago by embryologist and geneticist, Conrad Hall Waddington (1905-75). The idea of necessity path was used by Waddingon to describe the development process of different cells of biological organisms but in later works he has extended this idea to socio-economic processes. Waddington see the development of any single cell of biological organism as its movement in the so-called epigenetic landscape. He portrayed the process in his *Principles of Embryology* (Waddington, 1956, p. 412) by landscape of valleys representing different fates the cell might roll into (see Fig. 1). At the beginning of its journey, development is plastic, and a cell can become many fates. However, as development proceeds, certain decisions cannot be reversed.

Implicit in this model is the notion of canalization (and this idea is presented in his earlier work, namely in (Waddingon, 1941), where he writes that "developmental reactions...are in general canalized. That is to say, they are adjusted so as to bring about one end result regardless of minor variations in conditions during the course of the reaction." To Waddington canalization is not unlike the current notion of "developmental constraints".

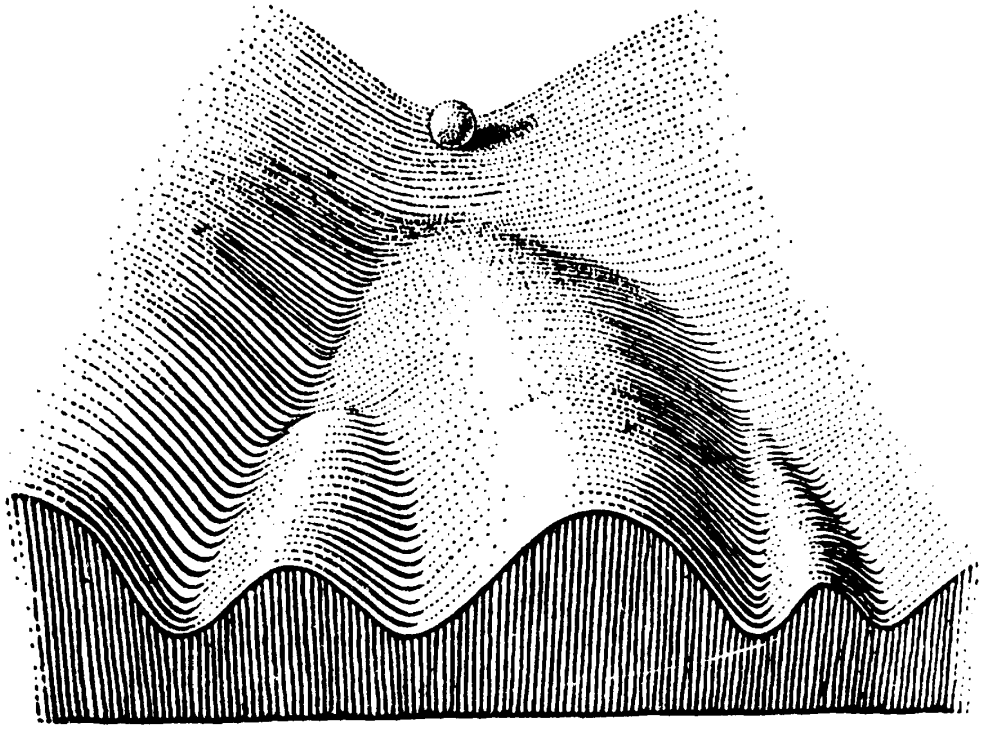

Figure 1. Epigenetic landscape and chreods

Very frequently general vision of development of dynamical system is based on cybernetic concept of negative feedback leading to the stable equilibrium. This regulatory process of stabilizing the development and tendency to return to initial equilibrium is called homeostasis. There is enormous number of examples of homeostatic systems in biological and socio-economic spheres of life.

But developing systems are changing all the time, moving along some defined time trajectory, from an initial stage, such as a fertilized egg, through various larval stages to adulthood, and finally to senescence. The regulation that occurs in such systems is a regulation not back to an initial stable equilibrium, as in homeostasis, but to some future

stretch of the time trajectory. The appropriate word to describe this process is homeorhesis, which means the restoration of a flow.

> "The stabilization of a progressive system acts to ensure that the system goes on altering in the same sort of way that it has been altering in the past. Whereas the process of keeping something at a stable, or stationary, value is called homeostasis, ensuring the continuation of a given type of change is called homeorhesis, a word which means preserving a flow. A phrase used to describe such systems, is to say that the pathway of change is canalized. For the pathway itself one can use the name chreod, a word derived from Greek, which means 'necessary path'. (Waddington, 1977)

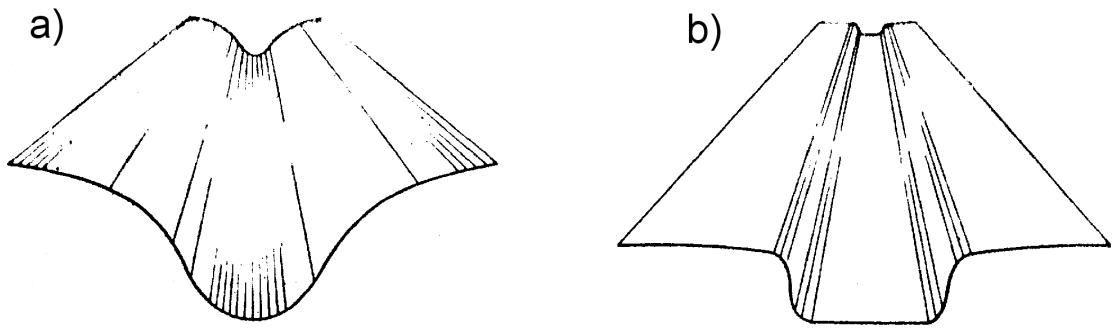

Figure 2. Chreods with different types of stability (Waddington, 1977)

Waddington see different types of chreodic development. If we compare different behaviours of a system we can identify small or high differences between trajectories of development of that system. For small differences the identified chreod will be similar to a narrow valley (a chasm, Figure 2a) and for relatively high differences (although with visible trend of development) we can say that the chreod has flat bottom valley (Figure 2b).