II. MODELS FOR NONLINEAR DECISIONS OVERVIEW AND TWO CASE EXAMPLES IN FINANCE AND ENERGY

Ionut PURICA[1]
Liviu Lucian ALBU[2]
Marioara IORDAN[2]
Sorin DINU[2]

Abstract

The latest years evolutions in the financial and economic world have once more proven that the models used to describe the behavior of given systems should be extended and the approach on which they are based should change from linear to nonlinear. A series of such models are described in the paper, with a synthesis of the main features of nonlinear behavior, and a case example is presented on how to describe in order to be able to predict the discontinuous decision associated with the financial crises and with the technological evolution of the energy systems. Suggestions are made on the need to control crises and not to eliminate them if one wants to better adapt to a nonlinear world dynamic and on the optimal scenarios for the penetration of fuel cell technologies for energy production.

Keywords: Nonlinear models, discontinuous decisions, financial crises, energy technologies
JEL Classification: C3, C61, C62, D7, D87

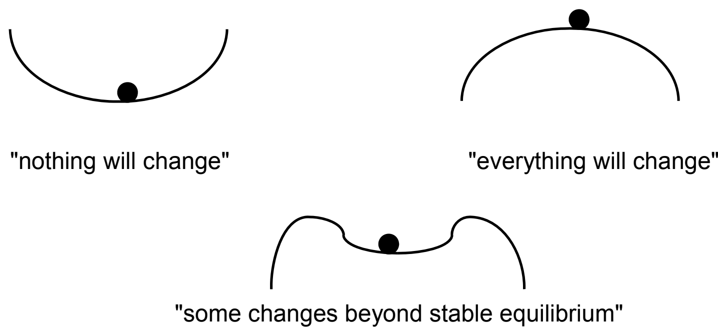
1. Introduction

The evolution of various infrastructures such as: communication, energy, transport, etc., for the whole planet and the ability to analyse big data has evidenced the limits of technological evolution and of environment (Blackmore, 2001; Dawkins, 1996a, 1996b; Dopfer, 2004; Foster, 1999a, 1999b; Hull, 1988). The technological limits have been shown to have a logistic behaviour, the new technologies replacing the old ones' dominance. The environmental limits, on the other hand, showed that Earth is a limited world that we hope to absorb the impacts of our actions to master energy and our lack of acceptance of existence of limits. In this context, there are three possible decision situations, as shown below (Purica, 2010):

[1] *Institute for Economic Forecasting, Romanian Academy. E-mail: puricai@yahoo.com*
[2] *Institute for Economic Forecasting, Romanian Academy..*

Figure 1

Actions and induced changes



A behaviour type of bifurcation occurs in the reaction to change, mostly when the limits are acknowledged. This creates a path from the extreme situations: “what you do will not change anything” or “anything you do will change it all” to a more complex situation “some actions will not produce a change while some others will”. A good example of amplified cycles is the build-up of cement dams to protect from the increase in sea level generated by the CO2 emissions of cement production.

By contrast to the “research” programs of several hundred years ago that strived for transforming everything into gold, we currently look for the energy conversion technologies as an indicator of welfare. The interaction complexity of various systems needs to introduce aggregated indicators and their variation according to different regions. Thus, the implementation of energy conversion should consider the cultural and socio-economic conditions of each particular region.

In order to make evolutionary decisions, there is a need for process representations, i.e. models that serve to scan the decision options. Over time, the mathematics of models passed from linear to nonlinear to accommodate the increased nonlinearities of the process dynamics (Gheorghe, 1979; Purica, 1991). Decisions to reallocate project finance, although common in reality, only in the recent years may be predicted by such nonlinear models (Purica, 2013; 2015, Helleiner, 1995; Allen, 1999, 2004; Krugmann, 1999; Leathers, 1999; Reinhart, 2007, 2008). A choice is opened to avoid or cross limits, the latter associated to producing shocks whose absorption forces the resilience of the systems. To recognize the limits is a different option that allows for changing them in order to go deeper into the systems’ interaction.

Considering energy and environment in evolution requires information that must be looked for and longer time constants (Ursu, 1979). Some provided actions could generate capital investments having long pay-back times, others, if postponed, may damage the environment in an irreversible way. Also, the new energy paradigm change that occurs currently requires a different regulatory environment (Marketti, 1978; Haefele, 1977). Moreover, the new infrastructures in the energy systems and telecommunications allow for a better monitoring of the environmental nonlinear impacts. We should not forget that the Lorenz model that describes weather shows a chaotic behaviour.

2. Evolution among limits

The limit is a characteristic concept of non-linear behaviour. It is not understood as the asymptotic linear limit but as a separation of various basins of behaviour of the system's dynamic. Evolution is frequently about crossing the limits, such as deciding to abandon a given project or to enhance another. The nuclear development in Italy – that abandoned it – and in France - that enhanced it – are examples of the mentioned kinds of evolutions (Purica, 2010).

2.1. Social limits

Various parameters are associated to social limits. Population is one of them, having both the meaning of purpose of production and of one of its elements, namely labour force. The projections of population evolution do not take into account the disrupting events such as natural disasters, epidemics, world wars, etc. (Pearl, 1978).

Alternatively, the economic evolution may be described considering the geometric structures involved. Cities as rectors of economic interactions may bear resemblance to the neutronic models of nuclear reactors (Purica, 2010). Thus, the dimension of a city depends on the intensity of reactions occurring there; moreover, the savings of residents behave as a saturation process and the Zipf's conjecture appears to be one atypical over the income process.

Energy is another measurable parameter in the socio-economic structuring. The structuring of the energy markets has been revealed to optimize the benefits of competition, with the costs of complexity shedding new light on the regulatory activity (Purica, 2008).

2.2. Technological limits

The creation and diffusion of technologies also show nonlinear patterns. For instance, the saturation of old technologies has triggered the perception of limits, which generated the occurrence of new technologies in order to use different resources and/or new concepts. The perception of environmental limits happening lately is likely to produce adapted technologies in order to restructure the interaction of economy with environment (Foster, 2005).

2.3. Environmental limits

At a local level, the human groups have known and reacted to the environmental limits, be they geographical or climate related. We have reached now the planetary limit and crossing, which means either extinction or leaving the planet to colonize other celestial bodies, such as Mars. There is also the option to control the impact and synchronize with the whole planet system.

3. The perception of changes in complex systems

3.1. Perception of complex processes

The green house (GH) effect has several time constants of its processes. Some may take decades, others may act in the short run, hiding the long-term effects. The perception of such complex interactions is also polarized by the capability of anthropic decision makers to realise the middle situation, where some actions do not change the system while others do. The cases of going to the linear limit occur either towards nothing will change or towards everything will change by given anthropic actions (Mayoral 2005a, 2005b; Nicolis, 1977; Purica, 2013).

3.2. From simple to aggregated

The best way to present the system dynamics consists in passing from individual indicators to aggregated ones. Thus, the possibility to see the second order behaviour of the given system occurs. The use of aggregated indicators is not new in physics, e.g., the criterial numbers in the hydro dynamics theories that mark the limits of flow change from laminar to turbulence. The economy interaction with environment is also better described by combined indicators, that go beyond the simple division towards more complex combinations of simple indicators.

3.3 Rich and poor second order migration effects

The rich and the poor economies show together different regimes of children labour and migratory behaviour. For example, children labour has two equilibrium points depending on the family income, signifying a bifurcation system model. Also, the migration between the poor and the rich economies is associated with a transfer of poverty to the rich economy, which at a given moment of saturation may reverse the migration flow back to the formerly poor economy. The Italian example is relevant in this context, having reversed the migratory flow in the mid-seventies (Purica, 2010).

3.4. Diffusion of new technologies

The diffusion of new technologies in a given economy is associated with the saturation of old ones. The model is that of cycles in a phase-space of a multi-dimensional system. Mathematical instruments such as the Fokker-Planck equation are used in some of these models. In a different line of thought, the production of innovations is modelled with the Cobb-Douglas formula similar to the general economic production. Moreover, the gain of experimental information shows a non-Shannon measure in a Minkovsky-type of space stemming from a multivalued logic approach

4. Decisions for development

4.1. Linear versus nonlinear models

The long-ago predictions of development revealed only linear increases with different slopes. Appearance of nonlinearities started with the depletion of resources that a given technology would use until saturation. Later limits were shown to be correlated with system's variables and parameters. These limit categories included saturation, but also encompassed more complex ones (Robinson, 1995; Reinhart, 2007).

4.2. Resilience – absorb crossing or avoiding limits

The first temptation when limits are known would be to avoid them. Assessing the shock, one may decide that crossing may be a better alternative. The nonlinear models allow for determining the moment in time when such a decision should be made to minimize the cost; thus, getting closer to the real-life situations.

4.3.Sustainability – limits recognized

To control the system's evolution trajectory, one may design the parameters such as to impose the limits. The conscious capability to recognize and possibly change the limits is specific to the concept of sustainability that considers the system dynamic evolution and the long-term effect of the current actions. To be aware of such effects, one needs appropriate indicators, by contrast with the situation when increasing health expenses due to an epidemic shows an increase in the GDP that is seen as progress.

The conclusion from the above-mentioned is that along with the produced material and the knowledge capital the environmental capital should also be considered. New indicators are needed to monitor the 'depreciation' of the latter capital.

Finally, considering the cycles in economy, one should mention that the velocity of rotation of money is a frequency measuring the economic cycle. A recent model associated this to the Scroedinger equation in quantum physics (Purica 2010).

We provide two examples of nonlinear models.

5. Nonlinear behaviour of financial crises

The credibility at the basis of financial world is supported by a set of patterns of behaviour having an unstable state of equilibrium. If credibility is lost, this may have strong detrimental consequences. The reaction diffusion of memes (mental conceptual entities) leads to the occurrence of specific collective behaviour. This type of change description is also encountered in the chemical and physical systems, as well as in the development of creative behaviour. In the niche of financial instruments, one instrument expands and reaches domination over the others in the market. This triggers more money allocation to finance that instrument. At the moment of perceived saturation, the allocation of funds is stopped and deviated towards other instruments, this being seen as a crisis. Monitoring this process with a logistic curve gives the possibility to predict the moment of change in trends (increase to saturation) and to react accordingly (Purica, 2015).

5.1.Taking advantage of the crisis

The occurrence of a crisis creates at the global level a chance for fast change in the entrenched behaviour towards new patterns. The awareness of the new evolutions possible after the crisis covers various elements of the learning effect of not repeating the crisis, avoiding the effect of 'short memory', to the change in the economic production priorities, such as to, e.g., diminish the greenhouse gasses emissions.

Thus, the dynamic stability does not involve the complete elimination of crises, but their incorporation in the economic evolution prepared to face them and take advantage of their aftermath. Only recently, models started to be devised allowing for the prediction of such behaviour.

6. Scenarios of the technological evolution model of the power market

We assess the robustness of our baseline SVAR specification in several ways. Also, we focus on reporting the associated findings with respect to the crucial IRFs, retrieved after running the panel SVAR-GMM model.

Definition of the scenarios is presented in the following, together with a set of preliminary results. The analysis will be extended in the second stage of the project, with the consideration of specific details.

The software used for the analysis is described below; they were developed by the IAEA (International Atomic Energy Agency) based on the original software from IIASA (International Institute for Applied System Analysis).

• *MAED-to estimate the annual energy demand (electrical energy and heat) for long term (2011-2070) in three possible evolution scenarios of society:*

– *Slow-pessimistic (D1),*

– *Reference-medium (D2),*

– *Rapid-optimist (D3).*

• *MESAGE-to generate optimal forecasts for the three nuclear scenarios associated with the equally probable options of political decision factors for the modelling period 2011-2070:*

– *Scenario nuclear low (S1),*

– *Scenario nuclear reference (S2),*

– *Scenario nuclear high (S3).*

The main characteristics of the considered preliminary scenarios are given below, and the preliminary results obtained are presented in the following figures.

SECTOR of NUCLEAR ENERGY:

• S1: only two CANDU units (existing + life extension)

• S2: four CANDU units – as in the national energy strategy 2013-2020, existing and in construction + life extension: also, sensitivity studies for three cost scenarios of investment capital

• S3: four CANDU units + new capacities NPP installed (gen III + after 2035: PWR/HWR Mix) + gen IV (ALFRED project under development).

SECTOR HEAT CLASIC & DISTRICT – optimistic hypothesis

• HYDRO (including pump-storage. renewables (wind parks & Solar PV. THERMO (existing/coal, lignite, gas; new/lignite, gas, inclusive heat district-distribution & storage)

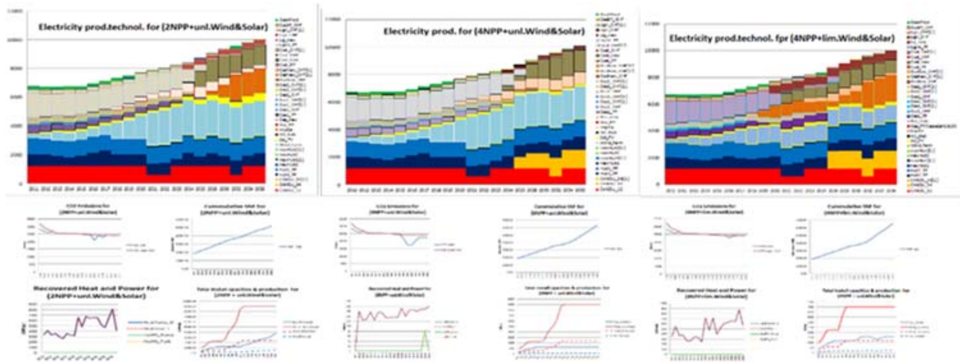
UNPROVEN TEHNOLOGIES in the first year of the modelling period:

• They are in development stages and their industrial use will be very costly,

• These technologies will be developed and used only in the case when the demand for energy will be higher than the capacity of proven technologies.

Figure 2

Scenarios of fuel cell penetration in the energy system



As shown in the figures above, the preliminary scenarios generate various evolutions related to the ratio of nuclear energy to renewables – which is strongly dependent on the input assumptions of each scenario.

Acknowledgments

The paper was written with the support of the financing contract no.25/Project "The engine of energy revolution based on Hydrogen - Fuel cells on the road from research to production by minimizing technological barriers" (Motorul revolutiei energetice bazat pe Hidrogen – Pilele de combustibil pe drumul de la cercetare la productie prin minimizarea barierelor tehnologice) PCCDI/2018 financed by UEFISCDI, Contractor National Institute for Research and Development for Cryogenic and Isotopic Technologies ICSI Ramnicu Valcea, Valcea, Romania, Subcontractor Institute of Economic Forecasting, Bucharest, Romania.

References

Allen, R.E., 1989. *Globalization of the US financial markets: the new structure for monetary policy*. International Economics and Financial Markets: The AMEX Bank Review Prize Essays. Oxford: Oxford University Press.

Allen, R.E., 1999. *Financial Crises and Recession in the Global Economy*, 2nd ed., Cheltenham/Northampton, MA: Edward Elgar.

Allen, R.E., Ed., 2004. *The Political Economy of Financial Crisis*, Cheltenham/Northampton, MA, Edward Elgar.

Blackmore, S., 2001. Evolution and Memes: The human brain as a selective imitation device. *Cybernetics and Systems*, 32(1), pp.225-255.

Dawkins, R., 1996. Viruses. In: G. Stocker and C. Schöpf, Eds. Memesis: The Future of Evolution. Ars Electronica.

Haefele, W., 1977. *On Energy Demand*. IAEA General Conference, Vienna. p.98-112.

Helleiner, E., 1995. *Explaining the globalization of financial markets: bringing states back in*. Review of International Political Economy, 2(2), pp. 315-341.

Hull, D.L., 1988. *Interactors versus vehicles*. In: H.C. Plotkin, Ed. The Role of Behaviour in Evolution. Cambridge: MIT Press.

Krugman, P., 1999. Balance sheets, the transfer problem and financial crises. *Journal of Money, Credit, and Banking*, 11, pp. 311-25.

Leathers, C.G. and Raines, J.P., 2004. The Schumpeterian role of financial innovations in the new economy's business cycle. *Cambridge Journal of Economics*, 28(5), pp. 667-81.

Marchetti, C., Nakicenovic, N., 1978. *The Dynamics of Energy Systems and the Logistic Substitution Model*. IIASA AR-78-18.

Mayoral, E. and Robledo, A., 2005a. *A Recent Appreciation of the Singular Dynamics at the Edge of Chaos*. Available at: <http://arxiv.org/abs/cond-mat/0501398> [Accessed March 2020]

Mayoral, E. and Robledo, A., 2005b. Tsallis' q Index and Mori's q Phase Transitions at Edge of Chaos. Phys. Rev. E, 72, 026209.

Nicolis, G. and Prigojyne, I., 1977. *Self-Organization in Nonequilibrium Systems*. London: Wiley.

Pearl, R., 1978. The Biology of Population Growth. Ch. 18. New York: Knopf.

Purica, I., 2015. *Nonlinear dynamics of financial crises – How to predict discontinuous decisions*. USA: Elsevier – Academic Press. ISBN: 978-0-12-803275-6.

Purica, I., 2013. *Occupy the Financial Niche: Saturation and Crisis*. In: Stavrinides, S., G. *et. al.,* ed., Chaos and Complex Systems. Springer Verlag Berlin Heidelberg, pag.125-130. DOI 10.107/9783642339141_16

Purica, I., 1991. *Synergetic application of complex ordered processes*. *Proceedings of ENEA Workshops on Non-linear Systems*, vol.3. Maino G.(ed) *Simulation of Non-linear Systems in Physics*. Singapore: World Scientific Publishing.

Purica, I., 2010. *Nonlinear Models for Economic Decision Processes*. London: Imperial College Press. ISBN 9781848164277.

Purica, I., 1988. Creativity, Intelligence and Synergetic Processes in the Development of Science. *Scientometrics*, 13(1-2), pp.11-24.

Purica, I., 1989. Creativity and the Socio-Cultural Niche. *Scientometrics*, 15(3-4), pp.181-187.

Reinhart, C.M. and Rogoff, K.S., 2007. Is the 2007 US sub-prime financial crisis so different? An international historical pattern. *American Economic Review: Papers and Proceedings*, 98(2), pp. 339-44.

Reinhart, C.M. and Rogoff, K.S., 2008. This time is different: a panoramic view of eight centuries of financial crises. *NBER*, working paper, No. 13761.

Robinson, C., 1995. Stability, Symbolic Dynamics, and Chaos. Boca Raton, FL: CRC Press.