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FORECASTING OF TIME-SERIES FOR FINANCIAL MARKETS

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Abstract. One of the four backbones to analyze time-series in general and forecast time-series for financial markets, particularly, is the Chaos-Theory. The four backbones are: Chaos-theory, Fuzzy logic, Neural networks and Genetic algorithms. Although each method itself is a powerful analytic tool, the present paper suggests to combine them to a hybrid analytic and analysis tool, where all methods interact and result in promising outcomes.
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1. Introduction. The Chaos-theory is a mathematical theory of dynamic systems, which describes this systems with deterministic, non-linear differential equations. The essential characteristic of chaotic systems is, that the 'time paths' of the variables are reacting highly sensitive to modifications of the boundary conditions; respectively: at only minimal changes of the boundary conditions, after a certain time there are completely different time paths: descriptive to illustrate using the example of a billiard game, at which already minimal differences of the impact lead to extreme variation of the alley. Thus, Chaos-Theory deals with the development or dynamic of non-linear systems (cf. Horn[1]).

2. Synergetics or self-organization. Referring to the past forthy years, science more and more often considers not only deterministic and stochastic processes, but another class of processes and events, as well. They are in principle *nonlinear* and in particular do not obey the *principle of superposition*. We shall disclose the detailed meaning of those notions for another publication. On one hand, these are deterministic processes, where quantitative changes take place as a result of the intensification of external impacts. The eventual difficulties of adequate characterization of those changes, as well as related management and control, are mostly technical. Note also that principle

obstacles occur when the objects of study undergo qualitative changes. It turns out, as mentioned above, that the smallest inaccuracy of measuring the initial state could grow in time and the corresponding system could attain a chaotic state. Due to sensitivity to initial data, the process transforms from deterministic, i.e. predictable, into stochastic, or at least, it resembles such a process. There occurs a so-called *chaos* or *deterministic* (*determined*) *chaos* which is one and the same. "Unfortunately, there is still no concise, exact and clear definition of chaos in modern scientific sense." (Panchev, 2001)

Usually, one would determine chaos descriptively. A typical example is the behavior of a pack of wolves looking for food. Another interesting example concerns the earthquake in Macedonia, 1963. Eyewitnesses said that hundreds of rats "invaded" the foyer of a hotel in Skopie after the first seismic quake and ran chaotically. One can observe chaos not only in biological systems, including systems where people participate. The event is typical for different areas, in Economics included. It is essential to note, however, the well-known fact that Nature has unique capabilities to control chaos and to establish order. For instance, lack of food makes the pack of wolves select a leader. The mechanism of that selection is not clear. As if, everything happens on its own, and order occurs within the pack as a result of the self-organization – the leader-wolf leads (controls) the pack to survival.

A group of human beings is also capable of reflection and self-organization. The group does something, thinks of it simultaneously thinking of what it is thinking about. Yet, man is not capable of predicting everything. Regardless of the high level evolution of the human brain, there are events that man cannot predict. It is enough to note here the results of the first tour of the presidential elections in France, April 2002. The unexpected success of the extreme rightists caused panic (chaos). The streets filled with protesting people, and there were cases of extreme behavior. Then, chaos gradually transformed into order, society underwent self-organization and the second tour of the elections calmed down the turbulence.

Considering the general case, one can not separate order from chaos. It turns out that chaos consists of an extremely complex ordering. Consider the enormous set of interrelated factors and parameters that affect the behavior of a system. Quite often, however, it is possible to separate its most important and key characteristics. Then, self-organization occurs in those cases, related to the determination of the basic factors known as *controlling parameters*. Complex systems have many degrees of freedom (sometimes hundreds), and this is the characteristic that makes them complex. Yet, there are some cases when one can order those degrees of freedom after the most important ones. Then, we say that a hierarchic system of control occurs, and the wolf-leader dictates it within the pack. Moreover, specific interrelations occur, called by

the physiologists *synergies* (*synergy* means common action in Greek). All this is due to the system capability of self-organization. The situation with the system of market behaviour is similar. The interaction between its elements and its self-organization yields capabilities to fulfil successfully a specific task, i.e. "to solve Economics problems".

A considerably young science deals with self-organization. It is known as *synergetics*. A book *Self-organization in non-equilibrium systems* by G. Nicolis} and I. Prigogine was issued in the USA in 1977 . It was translated in Russian in 1979 (Nicolis & Prigogine, 1979). The book deals with the theory of non-equilibrium *phase transitions* and processes of self-organization in physical, chemical and biological systems. Note that phase transition is the transition from one state into another that qualitatively differs from the initial one. We shall reduce our historical review to the example of different aggregate states, although that we consider here the *equilibrium phase transitions* as a specific case. The First International Symposium on Synergetics was held in Elmau, Germany, 1972. The Conference held in Brussels in 1978 was more significant. Its proceedings were issued in 1981. It is now assumed that the years 1977 – 1978 outline the period of synergetic emergence. The name "synergetics" was introduced in 1978, in the original of (Haken, 1980). In fact, synergetics was discussed long before Haken. Regarding modern concepts, however, the related events had quite a small number of the characteristics inherent in this notion. The English physiologist Charles Sherington used this neologism in 19-th century. For instance, the joint behavior of anatomic organs, as well as the combined effect of several pills, were called synergetic. Yet, the effect of summing pills was not a sum of the effects of each pill. (However, this is the case of violating the principle of superposition). One can come across this term in medicine, nowadays, although it is not precise. Later on, during the 60-ies of the 20-th century, the American mathematician Stanislaw Ulam spoke also about synergy, meaning the interaction between man and computer. At the same time, the American physicist-theoretician Norman Zabuski considered a synergetic approach to the unification of the capabilities of ordinary analysis with those of the computer calculations, regarding the discovery of solitons. Note that soliton is a new type of nonlinear wave which occurs when studying the famous problem of Fermi-Pasta-Ulam – the problem was solved by M. Cruscal and N. Zabuski in 1965 (Bushev, 1992).

A more detailed description of the basic characteristics of synergetics is given in (Grozdev, 2007) in connection with the preparation of talented students for participation in Mathematical Olympiads. Our aim is to apply some of them in-depth and to establish their presence in forecasting of time-series for financial markets. As shown mentioned below, foreteaching and planning are

complex processes that cannot be modeled easily without using synergetic ideas and methods. Things seem natural, especially when considering mathematical modeling. This is so, since on one hand, synergetics has an inter-disciplinary character. On the other hand, forecating and planning of economics system are related not only to Economics, but also to Mathematics, Information Technology, Psychology, Sociology, Control Theory, Artificial Intelligence etc. Self-organization, as the aim of forecasting of time-series for financial markets, is present both in the practice and activity of the participants in the corresponding processes. It arises during the process of self-organization, too, as a result of communication between people. This is one of the reasons why the activation of synergetic processes and the relation between them, is among the basic problems that financial markets face. Their successful solution is related to the design of appropriate instrumentation, development of adequate methodical means and carrying out of relevant activities. In fact, the present study treats those problems with regard to forecasting.

3. Chaos-theory, cause and effect relation. The main question: is the connectedness of knowledge and benefit linear? If one gets more and more money in a quiz show, if one knows more and more answers, one can say the benefit is linear to the knowledge. But: if one gets more and more chocolate bars, if one knows more and more answers, one can say the benefit is non-linear to the knowledge, because it is no benefit to get e.g. 100 000 chocolate bars for correct answers, where 100 000 Euros would be a benefit. As already mentioned, from a scientific view Chaos-theory belongs to the research area of nonlinear dynamics. Although in a chaotic system there is no linearity between cause and effect (causal connection) and chaotic system behave unpredictable, they follow of course laws of Nature and are therefore not random, per se; one converses of *deterministic* chaos. Like Edward Lorenz says in 1963: "The stroke of wings of a butterfly in the Amazon Region causes a hurricane in Florida." (Edward Lorenz (1917–2008) was an American meteorologist and mathematician. He is considered as the father of the Chaos-theory (butterfly wing stroke).)

"Clouds are no spheres, mountains no cones, coastlines no circles. The bark is not smooth – as well the blizzard carves its way not straight." (From the Introduction of Mandelbrots book "The fractal geometry of the nature (fractal from Latin frangere).) It is possible to decrypt the structure of a natural fractal and by computer models they can be reconstructed exactly.

As mentioned above, Chaos-theory is applied in Medicine, Cybernetics of management, Physics, Mathematics, Economics as well as in financial markets to forecast yields or stock prices.

For analyzing financial time-series of stocks, yields, currencies, indices etc., Chaos-theory applies a good insight to the data and is able to unveil

Figure 1 Ocean Wave, "Der Flügelschlag des Schmetterlings",
Dr. Reinhard Breuer, Deutsche Verlagsanstalt, Stuttgart 1993

hidden cycles and patterns. Edgar E. Peters offers in (Peters, 1991) "a new view of cycles, prices, and market volatility" in the context of pre-processing financial time-series.

4. Mathematical model of chaotic behavior: the magnetic pendulum. "The simulation is based on computing the motion of a metallic pendulum under the influence of three magnets." (Berg, 1994). The equations of motion

are integrated for all possible starting points in a two dimensional grid and where the magnet over which the pendulum came to a rest. The simulation is a good example for the so called butterfly effect. “The butterfly effect is a phrase that encapsulates the more technical notion of sensitive dependence on initial conditions in Chaos-theory. Small variations of the initial condition of a dynamical system may produce large variations in the long term behavior of the system.” The present paper will describe, ”a numerical model that demonstrates how small changes in the initial conditions of the simulation can result in large variations of the results. The result is an unpredictability of the simulation result since even the smallest change in the environment might effect the outcome dramatically. “The classical model assumes having a magnetic pendulum which is attracted by three magnets...” “The magnets are located underneath the pendulum on a circle centered at the pendulum mount-point. They are strong enough to attract the pendulum in a way that it will not come to rest in the center position.”…” Due to energy loss caused by friction, the pendulum will earlier or later stop over one of the magnets.”…” Magnets are assumed to cause a force proportional to the inverse square of the pendulum distance. In principle, this is akin to the Law of gravity or Coulombs law. All those laws are very similar, but of course, here we are dealing with (hypothetic) magnetic monopoles, not masses or charges. That assumption is in line with what everyone does when it comes to the pendulum and magnets simulation. In reality, Magnets are dipoles. A dipole causes forces proportional to $\frac{1}{r^3}$ rather than $\frac{1}{r^2}$. The force calculation does not take this into account although simulating a dipole by two monopole sources would be an option too. The Pendulum is assumed to be made up of iron neglecting eddy currents that would be induced in reality.”

The equation of motion:

“The pendulum movement is calculated by integrating twice over the accelerations acting on the pendulum. Normally, one would not talk about accelerations but forces. According to Newton’s First Law of Motion, the force necessary to move a body equals mass times acceleration. We solve that equation for the acceleration:

$$\vec{F} = m \cdot \vec{a} \ , \ \vec{a} = \frac{\vec{F}}{m} \text{ (Newton’s First Law)}$$

Since our initial conditions provide a starting position and a starting velocity (assumed to be null), all we need is to calculate accelerations. For simplicity, mass is assumed to equal one mass unit. Talking about units, we should mention that the simulation in general does not care much about

physical units. This is no problem since using real units would just impose scaling factors on the parameters. The following equations list all accelerations relevant for the simulation:"

Accelleration caused by gravitational pullback: $\vec{a_g} = k_g \cdot \vec{r}$

Accelleration caused by a single magnet: $\vec{a_m} = k_m \cdot \frac{\vec{r}}{|\vec{r}|^3}$

Decelleration caused by friction: $a_f = -k_f \cdot v$

Total accelleration of the pendulum: $\vec{a_t} = \vec{a_g} + \left(\sum_{m=1}^{3} \vec{a_m} \right) - \vec{a_f}$,

where

$\vec{a_t}$ – total pendulum accelleration;
$\vec{a_g}$ – accelleration caused by gravity pullback;
$\vec{a_m}$ – accelleration caused by magnet with index *m*;
a_f – accelleration caused by friction;
$\vec{v}$ – velocity of the pendulum;
k_f – friction constant;
$\vec{k_g}$ – strength of the gravity pullback;
k_m – strength of the magnet;
$\vec{r}$ – position vector of the pendulum.

(cf. Ingo Berg: demonstrating the butterfly effect with a magnetic pendulum)

Thus, the magnet pendulum shows the phenomenon of deterministic chaos. Small changes in the boundary conditions, generate big differences in the phenomena. Predictions get impossible, and we have a random result (Henry Poincaré assumption 1904).

5. Some popular examples. Following we will outline a case study, how Chaos-theory can be applied within another section of Economics, the Strategic management.

In a distribution branch of an EDP manufacturer (due to confidential reason, the company can't be named) the management decided to rearrange the organization – namely from functional product applied orientation towards target of a specific branch. It was planned to liquidate product oriented functional units in distribution, in software- and marketing domains. Instead

profit-center should develop, where marketing- distribution- and software consultants should concentrate on one target audience. Normally one would have got to work with strategic planning, organigrams, job specification and new procedure- and decision rules (Taylor).

This is where the management proceeded different. It has been guided by patterns and self-organization. Such patterns can be worked out by the qualitative analysis of success and failure projects, by interpretation of the company history and by analysis of the growth-strategy and strategy during the crisis. The evaluation of customer- and employee interviews clarified here the intensity of the company, on which to connect was necessary.

Two examples: once the company was outlined as a gyroscope, which is stable, because it is spinning very fast. In another comparison the company was described with a Grand Prix car, on which many mechanics – admittedly dedicated – but uncoordinated, mess about. This results indeed the motor runs, but the car is not getting any place and many components have big attrition. Both comparisons describe actually chaotic situations – at the same time they point to solution approaches. Which patterns of self-organization are inherent this "messages"? They reveal, that dynamic and commitment dominate in the company. In crises and stress situations however, competition instead of integration, intensified actionism and personal orientation dominate. Too many believe to know what the mistake is. The circulus vitiosus of the company lies in the following self-reinforcing loop:

crisis/uncertainty →reinforces→dynamic/actionism →reinforces….

At the same time it is clear, that a slow way of proceeding of the management would provoke opposition; if one would proceed slower, the gyroscope would tumble over. So, how this pictures could be used for the implementation of the management decision, that the reorganization could take place just in time? The management captured *personal orientation and the principle of dynamics* and decided the following: the personal team composition of strategic market-teams was appointed, which was initiated with one representative of the distribution, the software and the marketing department, each. For this managements success criteria have been agreed, a mix of corporate criteria. The market-teams got the mission for self-organization, more precise:

They had to develop for their branches over the next six month a market diagnosis and strategy, to conceptualize and test their organization, how the structure of their meetings should be, how the distribution of know-how and the resources should be organized. The old and the new organization methods worked during the next six month in parallel mode, to get a graduate transition. The market-teams were allowed to make use of external consultants, when

necessary. The experiences of the pilot project and the status quo has been discussed in open conversations and open questions have been resolved, monthly. The implementation of the reorganization went very fast with this few decisions.

Why the decisions had the wanted effect? The management captured dynamic and dedication (mandate for self-organization). Due to the market-teams and the concerted success criteria, the competition between the functional departments (where it hampered the success) has been shifted to competition between the market-teams. The management implemented continual monthly negotiations and feedback loops and gave up huge concepts with planning and organization manuals. Fast operating and trying correspond to the gyroscopic, which is fast, because it is spinning fast. The parallel operation of two organization methods appears maybe chaotic, but it sizes the positive element of Chaos: Confusion stimulates, only in turbulences something new develops.

The decision mix of the management included evident personal decisions (basis for networks), decisions for incentive schemes (open and narrow measure criteria for performance and success). It stimulated the **self-organization**, additionally, delegated the strategic and organizational expertise in formation and ensured, that the involved persons negotiated and analyzed their actions, permanently. Therein has been the success: Open and indirect we guide the right way, how the Chaos-theory can adapted to management tasks.

6. Conclusion. We hope we could interest the reader a bit to explore, "what keeps the world together, internally".

(*Johann Wolfgang von Goethe, Faust*)

NOTES

1. Prof. Dr. Gustav A. Horn, Hans-Böckler-Stiftung, Institut für Makroökonomie und Konjunkturforschung (IMK)

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