FORECASTING IN ECONOMIC SCIENCES IN THE CONTEXT OF CHAOS THEORY

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Abstract: The aim of the article is to determine the epistemological status of forecasting in economic sciences in the context of chaos theory. Achieving the aim required the use of logical analysis and conceptual construction. The article defines two criteria for recognising a given system as being chaotic. The first one (subjective) concerns the appearance of the complexity characteristic of indeterminism. The second one (objective) concerns the occurrence of the sensitivity of the system to the initial conditions. The study examines the occurrence of both traits in economic systems and finally concludes that the epistemological status of forecasting in economic sciences is negative.

Keywords: forecasting, chaos theory, epistemology.

1. Introduction

Any scientific theory is required to fulfil three functions – **descryiptive**, **explanatory** and **predictive** (Przybyła, 2001, p. 25). The subject literature discusses the possibility of implementing the predictive function in economic sciences (Dittmann, Szabela-Pasierbińska, Dittmann, and Szpulak, 2017). The most radical approach, referred to as **instrumentalism**, assumes that the main objective of formulating any scientific theories is forecasting (Popper, 2002, p. 54). In that approach, their effectiveness is more important than meeting the criterion of the scientific truth. In instrumentalism, any intellectual aspirations are treated as measures that help to meet the practical needs (and therefore, instrumentalism is a special type of pragmatism) (Grobler, 2006, p. 257). Representatives of instrumentalism in the philosophy of science include, among others, E. Mach, M. Schlick or L. Wittgestein (all belonging to the so-called Vienna circle) (Popper, 2002, p. 54). Instrumentalism has many supporters among the representatives of economic sciences – one of the most famous of them was M. Friedmann (winner of Nobel prize) (Friedmann, 1953, p. 8-9). On the other hand, in the history of economic thought, a number of people taking the approach opposite to the predictive function of the economic theories can be indicated. A representative of such an approach was e.g.

J.S. Mill who propagated the futility of the predictive function of economic sciences (Gorazda, 2014, p. 179). Among the critics of the predictive function of economic sciences, the representatives of the Austrian school should be mentioned, in particular: L. von Mises, M.N. Rothbard, J.H. de Soto, M. Skousen, or H.H. Hoppe (Hoppe, 2011).

Doubts concerning the fulfilment of the predictive function of scientific theories by economic sciences are illustrated in the subject literature through repeated questions about the reliability of economic forecasts (Gospodarek, 2012, p. 121). However, in any science, the issue of reliability of forecasts is secondary in comparison to its detailed philosophies (e.g. philosophy of mathematics, philosophy of physics, philosophy of economics), especially in the epistemological area. And therefore, the basis for determining the reliability of weather forecasts is the epistemological status of weather forecasts the basis for the reliability of the sociological forecasts is the epistemological status of sociological forecasts, and the basis for the reliability of economic forecasts is the epistemological status of economic sciences. Even though numerous discussions concerning the reliability of forecasts can be found in the literature, it can be seen that there is no epistemological basis for forecasting in economic sciences. This article is to fill the gaps in this scope, at least partially.

The aim of the study is to determine the epistemological status of the economic forecasting. The theoretical basis for achieving the aim indicated in this study is the theory of chaos. Due to the fact that the aim of the study is of a systematising and cognitive character, the methods of logical analysis and conceptual structure were used.

2. Chaos theory

In Polish, the simplest meaning of **"chaos"** is disorder (sjp.pl/…). The etymology of the term "chaos" is probably related to ancient Greece where it was used in order to describe the matter from which the world was created. The universe – order emerged from chaos – disorder (Tatarkiewicz, 1981). In the 1960s E. Lorenz gave rise to a new field of knowledge, which is called the **chaos theory** (Lorenz, 1963, p. 130-141). Thus, the concept of chaos aroused the interest of researchers from many fields and disciplines of science (Krupski, 2010). However, the meaning of the term "**chaos**" causes a lot of mistakes and misunderstandings related to the interpretation and the description of the chaos theory. Adopting the attitude of philosophical determinism[1] allows us to assume that all states and phenomena of reality result from **cause and effect phenomena** (Mises, 2012, p. 21-22). This means that chaos is *a priori* impossible in the real world because it is ruled by deterministic laws. This does not mean, however, that all these laws are known to humans, or that they can

[1] Such an approach – which is contrary to indeterminism - is currently presented by a number of philosophers, e.g. Woleński J., Honderich T., Dennett D., Searle J. or Harris S.

be understood by them. Inability to get to know the cause and effect relationships that led to the state of the given system may result from three elements (Tempczyk, 1995, p. 198-199):

1. Too many components of the system – **complexity problem.**
2. Problems with the observation of system components - **measurement problem.**
3. Inability to solve systems of differential equations describing the system dynamics – **computational problem**.

Consequently, the term "chaos" does not characterise random (chaotic) phenomena but a specific type of order (Krupski, 2010, p. 5; Krupski, 1999). So, it is not so much that "chaos" is used in a sense differing from its original (and colloquial) sense but as that chaos theory uses the term "chaos" in a sense completely opposite to its original (and colloquial) one. Recognising the contradiction resulted in the literature widely using the term "**deterministic chaos**" (Wyciślak, 2009, p. 37-38). Logic refers to it as a **name absurd** as the name connotations feature mutually exclusive properties (e.g. square wheel, married bachelor, etc.). Thus, **deterministic chaos** is essentially **deterministic order** (cosmos within the meaning assigned to it by ancient Greeks), which only appears to be disorder (chaos). Consequently, this article further uses the term name absurd, that being **deterministic chaos**[2]. Subject matter literature indicates that **deterministic chaos is a property of certain systems**, and it is presented as a property of **physical systems** (nature components) or as a property of **abstract systems** (mathematical systems).

The dynamics of physical systems (inherently non-linear) is determined by the **deterministic laws of nature** (physical laws). In some physical systems, the level of complexity is so high that the external observer may perceive their evolution as indeterminate, as only the effects of a series of determinate processes occurring in a given system can be perceived. Thus, the observer may perceive the determinate system as chaotic, which is obviously only apparent. Therefore, **the first criterion for** considering a given **system to be deterministically chaotic** is the **complexity** as a result of which **determinate physical processes** may be perceived as **random** (chaotic) (Heller, 2008, p. 101; Ćwik, Jóźwiak, and Mariański, 2011, p. 97-105). At the same time, the condition of some physical systems in time t+1 is highly dependent on the state of the system in time t. Even a minimal change of state of the system in time t (initial conditions) may sometimes cause significant changes of the system in time t+1. This means that the state of some physical systems is very sensitive to their previous states. **Another criterion for** considering a **physical system to be deterministically chaotic** is therefore high sensitivity of its state to its previous states (Krupski, 2008, p. 211-213).

[2] It seems unjustified to formulate the concept of "order theory" instead of "chaos theory" because it would destroy a linguistic tradition abruptly. It was considered that it would be better to use a name absurd than the term chaos which in fact would mean order. Thus, and first of all, we do not abandon the linguistic tradition when using the name "deterministic chaos"; second of all, we bear in mind that in fact we describe phenomena which have nothing to do with disorder.

Thus, a prerequisite for considering a physical system to be chaotic is, first of all, its **high complexity of simulating chaos** and the **high sensitivity of the system state in *t*+1 to the state of the system in time *t***. Both of the foregoing prerequisites, however, are characterised by a very low level of precision. So defined criteria hinder classification of systems into chaotically determinate and chaotically indeterminate ones. Physical systems have been observed for thousands of years, it was not until the 20th century that E. Lorenz, owing to the ability to mathematically model the dynamics of physical processes, formulated the main principles of chaos theory. The ability to mathematically model complex physical phenomena makes it possible to determine strict criteria for the existence of deterministic chaos.

In abstract (mathematical) systems, chaos is understood as a property of certain equations or systems of equations, differential equations in particular. Abstract systems chaos is easiest to understand when illustrated with an example. The sequence of twenty numbers may be considered: 0.3000; 0.8190; 0.5781; 0.9512; 0.1811; 0.5783; 0.9511; 0.1814; 0.5791; 0.9506; 0.1831; 0.5834; 0.9479; 0.1927; 0.6067; 0.9306; 0.2519; 0.7349; 0.7599; 0.7117. Although all the listed numbers are in the range (0.1), but it is intuitively sensed that their consecutive values are random. The randomness of those numbers is only apparent, though. It is in fact a sequence resulting from the following, very simple **recurrence equation**:

$$\mathbf{x_n+1 = 3.9\, x_n\, (1-x_n)} \quad (1)$$[3]

In mathematics, the formula for $f(x) = ax\,(1-x)$ is called logistic mapping. For parameter a of the value of 3.9, further values resulting from the recurrent equation (1) appear to be a sequence of random (chaotic) numbers (Galias, 2003, p. 31). Such numbers are referred to as pseudorandom numbers. Pseudorandomness of this sequence of numbers thus represents **the first property** of **deterministic chaos** relating to the abstract (mathematical) systems – **the apparent indeterministic complexity**. Therefore, the occurrence of another property of deterministic chaos in these types of systems should be taken into account – **sensitivity of the system to changes in the initial conditions**. In the sequence expressed with a recursive formula (1), the first value of the sequence (which is 0.3000) was replaced with the value of 0.2900. Further numbers of a so created a sequence are as follows: 0.2900; 0.8030; 0.6169; 0.9217; 0.2815; 0.7888; 0.6497; 0.8876; 0.3890; 0.9269; 0.2642; 0.7581; 0.7153; 0.7943; 0.6373; 0.9015; 0.3464; 0.8829; 0.4031; 0.9384. For instance, a change of the value of the first one by barely 0.01 (3.33%) results in:

- a change of the value of the fourth number in the sequence by more than 50%,
- a change of the value of the sevent number in the sequence by more than 50%,
- a change of the value of the thirteenth number in the sequence by more than 300%[4].

Therefore, it turns out that at least some equations or systems of equations are characterised by the apparent indeterministic complexity and high sensitivity of the system to changes in the initial conditions. Thus, the deterministic chaos may be regarded as the

[3] It is assumed that the first number in the sequence (x_0) is 0.3.
[4] Pearson correlation coefficient between the first ten values of both sequences is barely 0.55.

property of certain systems which consists in apparent indeterministic complexity and high sensitivity to the changes of the initial conditions – regardless of whether one is dealing with physical or abstract (mathematical) system.

3. Essence of economic systems

Identification of **deterministic chaos** in economic systems requires the verification of the occurrence of its two basic properties, namely **apparent chaotic complexity** and sensitivity of the system to the **change of the initial conditions** (Siemieniuk, and Siemieniuk, 2015, p. 183-184). Achievement of the established objective requires prior presentation of the assumed terminological convention concerning economic systems.

Market is the basic concept for economics. In this paper, it was assumed that the **market** is **the whole of interchangeable relationships between the entities** (Mantura, 2015, p. 15). The whole of entities and relationships that are interchangeable between them can be treated as a type of **dynamic system** in which active people are one of its elements. The science that analyses the market is called economics. Thus, the **economics** may be understood as the **science of the general relationships which are interchangeable between the entities**[5]. **Market** as a whole of relationships interchangeable between entities constitutes **the system** understood as a **system meeting the formal conditions of the network through the adaptation of at least two linked subsystems** (Kempisty, 1973, p. 430)**,** or as a **set of elements and relationships between them** (Mazur, 1976, p. 8-12). Thus, **any system in which the phenomenon of exchange between parties** occurs can be called an **economic system**. The biggest possible system is, therefore, a system composed of a set of relationships of exchange between all people. This system has a number of subsystems. Examples of specific categories of economic subsystems include e.g.: family, company, region, country, or the stock market.

[5] The nature of the exchange relationship is its symmetrical character. Parties to the exchange are always an operating entity and another external entity. These Parties influence each other on the basis of feedback. The subject of the exchange is a concept with a wide range of meaning - it may include products, services, commodities, works, goods, information, emotions, feelings, etc. Examples of economic macrosystem **entities**: manufacturers, suppliers, buyers, households, banks, stock exchanges, states, local self-governments and many others.

4. Apparent chaotic complexity of the economic systems

In the systems theory, economic systems are considered to be among the most complex systems in general. Sometimes, an imprecise term of "large systems" is used to determine the scale of such systems. Large systems include, e.g.: manufacturing plants, branches of the economy or the national economy (Pszczołowski, 1978, p. 238). Both enterprises and the free market as a whole are considered to be "extremely complex" (Kempisty, 1973, p. 430). At the same time, despite the fact that the immanent element of all economic systems is individuals that carry out the exchange processes – people, this system is dynamic. The assumption that economic systems immanently contain the first property of chaotically determined systems requires, apart from stating its complexity, the demonstration that this complexity is apparently chaotic. The term "apparent" or "apparently" is, of course, imprecise and depends on the subjective perception level of the cognitive subject.

As the sense of chaos is not an objective phenomenon, it is impossible to use intersubjective tools to measure it. However, significant similarities between the phenomena of a physical character (e.g. weather phenomena) and phenomena of economic character can be noticed. Presenting the deliberately chosen example, Figure 1 shows the structure of air temperature in May 2017 in Poznań. A line graph formed is characteristic of the dynamic physical system on the basis of which E. Lorenz formulated the grounds for the deterministic chaos theory.

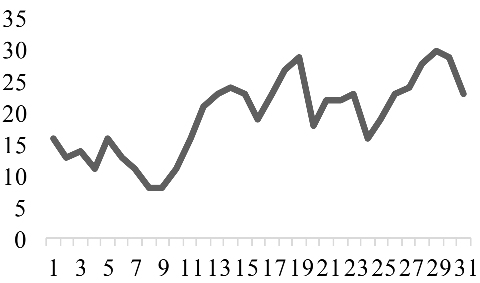

Figure 1. Temperature in Poznan in May 2017. Source: author's own study based on http://www.accuweather.com/pl/pl/pozna/276594/may-weather/276594, 29.06.2017.

On the other hand, figure 2 shows the WIG20 closing quotations in May 2017.

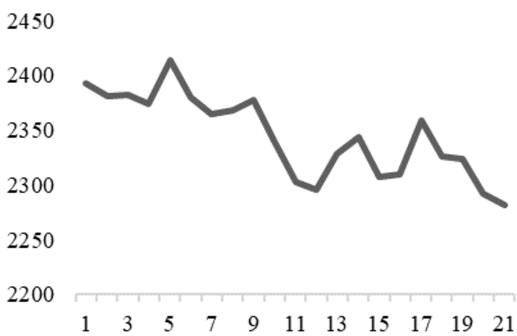

Figure 2. WIG20 closing quotations in May 2017. Source: author's own study based on http://inwestycje.pl/gielda/profil/WIG20, 29.06.2017.

Clearly, the presented graphs show the similarity between the examples of the phenomena of physical and of economic nature. Thus, if in the subject literature numerous physical processes (e.g. weather) are assigned a property of apparent chaotic complexity, it can be *analogically* concluded that this property occurs also in case of economic systems.

In the case of the impossibility of discovering absolute and deterministic laws governing economic systems that significantly impede their understanding, it is possible to use the models being a substitute for cause and effect cognition[6]. The most popular collection of tools of this type is proposed by **probability theory**. Processes which can be understood only by building probabilistic models (and not by formulating a series of deterministic laws) can be described as apparent chaotic processes. **If such systems are at the same time complex, we call them apparent chaotic complex systems.**

Despite the considerable complexity of the physical processes, a number of researchers (such as E. Lorenz) are able to model them – e.g. using differential equations. In the case of economic system, the determining of equations describing the behaviour of people is impossible. It is caused, among other things, by the absence of any constants describing human actions (Mises, 2000, p. 27-32). In the case of many natural processes, certain constants have been known for hundreds of years. Thus, the deterministic chaos occurs less often in dynamic economic systems than in dynamic physical systems, e.g. concerning the weather.

5. Sensitivity of economic systems to initial conditions

Even though the complexity of the economic system was analysed from a holistic perspective, it is easier to settle the issue of sensitivity of the economic system to its previous states on the basis of nominalism. In fact, each individual person constitutes one of subsystems of the economic system. At the same time, the opinion, according to which all the conditions associated with the exchange processes of every human being are a complex system in themselves, seems indisputable. The identification of properties of sensitivity in the system consisting of a single human being will, therefore, enable the carrying out of the *a minori ad maius* reasoning, under which the sensitivity of all economic systems to the change of the initial conditions must be recognised.

The processes of exchange performed by people constitute particular cases of actions, and therefore, of any intentional behaviour (Kotarbiński, 1969). Immanent elements of every human action are, apart from objectives, measures of action, and therefore, these elements of

[6] R. Cantillon pointed out that "*even if the assumption concerning the truthfulness of the established cause-and-effect relationships was correct, the complexity of the studied matter rather condemns the attempts to formulate strict laws to failure*"; after: Gorazd, M.: op.cit., p. 122.

reality, which in the opinion of the person performing the action are aimed at achieving the objectives. One of the most important factors determining the structure of objectives and measures of action of each individual is the **knowledge** possessed by him/her, and therefore, the set of his/her judgments about reality (Woleński, 2007, p. 368). Knowledge of the cognitive subject has a direct impact on both the nature of the objectives specified and the perception of the measures that would be used to achieve them. Feedback can be noticed between the subject and actions taken by him/her, which consists in the fact that the obtained information about the effects of the action performed influences the knowledge of the person performing it and, at the same time, on the structure of objectives and measures of the action obtained. Thus, the knowledge acquired during the performance of actions changes the basis of the further behaviour of individuals) (Gorazda, 2014, p. 11). If the knowledge which is the result of one action may substantially change the basis of the behaviour for the next action, the opinion according to which the economic system consisting of a single human is sensitive to initial conditions appears appropriate. On the basis of *a minori ad maius* reasoning, it can be concluded that all economic systems are sensitive to initial conditions.

Therefore, specific properties of economic systems include:

1. **Complexity**, which in the opinion of the observer may be apparently indeterministic.
2. High **sensitivity** of the state of the system in relation to the previous states.

Thus, economic processes are characterised by deterministic chaos.

6. Epistemological status of forecasting in economic systems

The source literature points to a number of restrictions concerning the forecasting in the scope of systems which are characterised by deterministic chaos. For example, the forecasts concerning the states of weather (physical) systems do not exceed the 30-day horizon. Each forecast exceeding the period of two weeks is based on statistical forecasting which builds on historical data and not on the status and evolution of the physical system. Therefore, the epistemological status of weather systems forecasting should be – in the short period (not longer than 30 days) – regarded as positive and in a period exceeding 30 days – as negative.

In the case of chaotically determined economic systems, no mathematical equations describing the evolution of such systems are known. The computational problem is correlated with the occurrence of the problem of the complexity of these systems. At the same time, despite the fact that the immanent component of any economic system is the human knowledge, it is impossible to determine the initial state of the system analysed. Thus, in economic systems, it becomes impossible to forecast the future states because of the coexistence of three problems: complexity, calculation and measurement problem.

Considering the above, it should be stated that the epistemological status of forecasting in economic sciences is negative – both in the short and in the long period.

7. Conclusions

The aim of the study is, therefore, to determine the epistemological status of the economic forecasting. The theoretical basis for achieving the aim indicated in this study is the theory of chaos. Due to the fact that the aim of the study was of a systematising and cognitive character, the methods of logical analysis and conceptual structure were used.

The most important achievements of the study include:

1. Carrying out a logical analysis of the concept of deterministic chaos.
2. Indicating a subjective criterion for recognising the system as chaotically determined – the apparent indeterministic complexity.
3. Indicating an objective criterion for recognising the system as chaotically determined – system sensitivity to initial conditions.
4. Stating that both conditions are met by economic systems.
5. Indicating that epistemological problems associated with the reliability of the forecasts, i.e. complexity problem, measurement problem and computational problem in the economic system are exemplified with higher intensity than in physical systems.
6. Making a statement concerning the fact that the epistemological status of forecasting in economic sciences is negative.

On the basis of the conclusions presented, it can be stated that the objective of the article was achieved.

Bibliography

1. Ćwik, M., Jóźwiak, K., Mariański, A. (2011). Wprowadzenie do zastosowania teorii chaosu w zarządzaniu ryzykiem. *Zeszyty Naukowe, s. Organizacja i Zarządzanie, 57.* Gliwice, Wydawnictwo Politechniki Śląskiej.
2. Dittmann, P., Szabela-Pasierbińska, E., Dittmann, I., Szpulak, A. (2017). *Prognozowanie w zarządzaniu przedsiębiorstwem*. Oficyna a Wolters Kluwer Business.
3. Friedmann, M. (1953). The Methodology of Positive Economics. In M. Friedmann, *Essays in Positive Economics.* Chicago: Chicago University Press.

4. Galias, Z. (2003). *Metody arytmetyki przedziałowej w badaniach układów nieliniowych.* Kraków: Uczelniane Wydawnictwa Naukowo-Dydaktyczne Akademii Górniczo-Hutniczej im. Stanisława Staszica.
5. Gorazda, M. (2014). *Filozofia ekonomii.* Kraków: Copernicus Center Press.
6. Gospodarek, T. (2012). *Aspekty złożoności i filozofii nauki w zarządzaniu.* Wałbrzych: Wydawnictwo WWSZiP.
7. Grobler, A. (2006). *Metodologia nauk.* Kraków: Wydawnictwo Aureus i Wydawnictwo Znak.
8. Heller, M. (2008). *Ostateczne wyjaśnienia wszechświata*. Kraków: Universitas.
9. Hoppe, H.H. (2011). *Ekonomia i etyka własności prywatnej. Studia z zakresu ekonomii politycznej i filozofii*. Warszawa: Fijorrr Publishing.
10. http://inwestycje.pl/gielda/profil/WIG20.
11. http://www.accuweather.com/pl/pl/pozna/276594/may-weather/276594.
12. https://sjp.pl/chaosu.
13. Kempisty, M. (ed.) (1973). *Mały Słownik Cybernetyczny*. Warszawa: Wiedza Powszechna.
14. Kotarbiński, T. (1969). *Traktat o dobrej robocie.* Wrocław-Warszawa-Kraków: Ossolineum.
15. Krupski R. (ed.) (2008). *Elastyczność organizacji.* Wrocław: Wydawnictwo Uniwersytetu Ekonomicznego.
16. Krupski, R. (1999). Teoria chaosu a zarządzanie. *Organizacja i Kierowanie, 2(96).*
17. Krupski, R. (2010). Istota i krytyka koncepcji organizacji działającej na krawędzi chaosu. *Zeszyty Naukowe WWSZiP, 14(1).*
18. Krupski, R. (2010). Kontekst chaosu w planowaniu strategicznym. *Przegląd Organizacji, 3.*
19. Lorenz, E. (1963). Deterministic Nonperiodic Flow. *Journal of the Atmospheric Sciences, 20(2).*
20. Mantura, W. (2015). Rozważania o współczesnych problemach marketing. *Studia i Prace Wydziału Nauk Ekonomicznych i Zarządzania Uniwersytetu Szczecińskiego", 39, 2.*
21. Mazur, M. (1976). *Pojęcie systemu i rygory jego stosowania. Cz. 2, Elementy wiedzy podstawowej.* Orzysz: Szkoła Podstaw Inżynierii Systemów.
22. Popper, K.R. (2002). Logika odkrycia naukowego. Warszawa: Fundacja Aletheia.
23. Przybyła, M. (ed.) (2001). *Organizacja i zarządzanie. Podstawy wiedzy menadżerskiej*. Wrocław: Wydawnictwo Akademii Ekonomicznej.
24. Pszczołowski, T. (1978). *Mała encyklopedia prakseologii i teorii organizacji.* Wrocław: Ossolineum.
25. Siemieniuk, N., Siemieniuk, T. (2015). Teoria chaosu deterministycznego a decyzje inwestorów giełdowych. *Zeszyty Naukowe Uniwersytetu Szczecińskiego, 74, 1.*
26. Tatarkiewicz, W. (1981). *Historia filozofii, t.1*. Warszawa: PWN.

27. Tempczyk, M. (1995). *Świat harmonii i chaosu*, Warszawa: Państwowy Instytut Wydawniczy.
28. von Mises, L. (2000). The Equations of Mathematical Economics. *The Quarterly Journal of Austrian Economics, 1*.
29. von Mises, L. (2012). *Teoria a historia. Interpretacja procesów społeczno-gospodarczych.* Warszawa: Instytut Ludwiga von Misesa i PWN.
30. Woleński, J. (2007). *Epistemologia. Poznanie, prawda, wiedza, realism.* Warszawa: PWN.
31. Wyciślak, S. (2009). Wykorzystanie teorii chaosu w zarządzaniu przedsiębiorstwem. *Organizacja i Kierowanie, 1(135)*.