Formal aspects of resilience

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Abstract: *The concept of resilience has represented during the recent years a leading concern both in Romania, within the European Union and worldwide. Specialists in economics, management, finance, legal sciences, political sciences, sociology, psychology, grant a particular interest to this concept. Multi-disciplinary research of resilience has materialized throughout the time in multiple conceptualizations and theorizing, but without being a consensus between specialists in terms of content, specificity and scope.*

Through this paper it is intended to clarify the concept of resilience, achieving an exploration of the evolution of this concept in ecological, social and economic environment. At the same time, the paper presents aspects of feedback mechanisms and proposes a formalization of resilience using the logic and mathematical analysis.

Keywords: resilience, systems, feedback, inverse connection, adaptive capacity, fragility, antifragilitaty, robustness

JEL Classification: A10, O17, P00

Introduction

The concept of resilience has been the subject of some interesting and controversial debates starting from RH MacArthur's article from 1955, referring to the modern study of stability in ecology field: "The fluctuations of animal populations and the measure of community stability." Given the R.H. MacArthur's statement the researchers have investigated different aspects of the concepts: stability, permanence, strength, resilience and variability.

The paper has the following structure: exposure of debates and controversies existing in the literature regarding the concept of resilience and the boundaries of this concept in relation to other concepts, description of feedback mechanisms, resilience formalization using as an example the Cobb Douglas production function.

In 1973, the ecologist C. S. Hölling relates to ecosystems resilience as being: "their capacity to absorb unforeseen shocks and disturbances without collapsing, self-destructing or entering such undesirable conditions". Recent studies show that resilience is applicable not only to ecosystems but also to social and economic systems. Thus, we mention the following researchers interested in the economic approach of the resilience concept: the researchers Rose (2004, 2007) and Chang (2009) and the researcher Engberg-Pedersen.

In the field of behavioral psychology, the researchers Masten et al. (1990), Kaplan (1999), Luthar and Becker (2000), O'Doherty Wright et al. (2013) analyze the resilience concept, reaching the following conclusion: resilient people are capable of self-renewal and adaptation, while those less resilient degrade and are adversely affected by stress factors.

The author, Nassim Nicholas Taleb, in his book "Antifragile. Things that gain from disorder " (2012), offers one of the most complex and current approaches on the resilience concept. The author clarifies aspects of the resilience concept by introducing the concept of antifragility in the literature: "the resilient withstand shocks and remains the same; the antifragile gets better."

1.1. The concept of resilience

Recent studies pay particular attention to the analysis of complex systems, often characterized by non-linear dynamics and unpredictable results. Thus, subjects like ecology, biology, sociology, but also economy, focus on behavioral aspects of non-linear dynamical models given the feedback loops, synergistic answers, and also the adaptive behavior.

The concept of resilience is based on the assumption that different states of a system involve different points of equilibrium, so that the systems development is based on the system's ability to move from one state of equilibrium to another.

Further, we will refer to the manner in which the concept of resilience is approached within Complex Adaptive Systems Theory. We will also consider aspects of the four concepts: resilience, robustness, fragility, antifragilitaty, from the author Nassim Nicholas Taleb's perspective.

We will make some clarifications on the five properties of the complex adaptive systems: emergence, self-organization, pathway dependence, blocking in state and resilience.

Among the scientific community which addresses the topic of Complex Adaptive Systems, the emergence of a system can be defined as: “the features of a system do not result from the summing of system components, but from the interaction between the components’, (Lansing şi Kramer, 1993) and the researchers O’Sullivan (2004) and Martin and Sunley (2007) highlight the close link between emergence, self-organization and resilience: often the complex systems are self-organizing themselves regardless of external conditions, the result being an emergent structure that has a highly variable resilience potential, depending on its stage of development.

The concept of self-organization implies a self organization that emerges from inside, not being imposed or ordered by an external entity, even if the organizer impulse may derive from outside the system.

The concept of pathway dependence is first used by the researcher Paul David who gives it the following definition: “a stochastic process of pathway dependence is one of which asymptotic pathway evolves as a consequence of its own historical processes”. (David, 2000, p. 5).

Interesting is the opinion of Page (2006). The author believes that non-linearity is the one that generates the pathway dependence, this being set of rules that interact locally and which is changed once with the system dynamics. A consequence of pathway dependence consists in the existence of more attractors between which the system variables choose to tend at some point to its evolution.

The concept of blocking in state is defined by Redding (2002) as: the effects of the occurrence of pathway dependence process; the pathway dependence occurrence creates the premises of installing the blockage if positive feedbacks are the dominant majority.

Pendall et al. (2010) and David (2000) believe that in order to exit this blockage state it is needed the intervention of some shocks from outside the system, which will cause changes in the system structure or may lead to the change of relations between system components. Thus, in this case, the system must not be resilient, because it needs to change its structure and the relationships between components, maybe also its functionality.

1.2. Resilience, robustness, fragility, antifragilitatea – concepts clarification

We shall refer to the four concepts from the author Nassim Nicholas Taleb’s perspective.

The author proposes the concept of antifragility and makes an analysis of the fragile systems, resilient, robust and antifragile in his paper. The author refers to the fact that antifragility delimits the boundary between what is alive and organic (or complex) and what is inert.

Thus, given the exposures of the author on the four concepts, we shall make the following clarifications:

- Resilience represents the strength of the system on internal and external disturbances; has elastic feature.
- Robustness is the strength of the system on the internal and external disturbances.
- Fragility involves more loss than gain, i.e. more disadvantages than benefits, i.e. unfavorable asymmetry – following the action of internal and external disturbances.
- Antifragility involves more gain than loss, i.e. more advantages than disadvantages, i.e. favorable asymmetry - following the action of internal and external disturbances.

We shall use the following illustration in order to present these issues:

Figure 1. The system behavior after the action of perturbation

2.The resilience formalization

2.1.The feedback mechanism

Based on Complex Adaptive Systems Theory, feedback represents an essential feature of these systems by assuming the existence of some connections and interdependencies. The principle underlying the creation of a feedback loop is simple but the feedback loop effects are particularly complex due to the diversity of situations in which it occurs.

As defined by Golec (2004), feedback is: "the influence exerted over the input by an output part ". There are two types of feedback mechanisms: positive feedback and negative feedback.

Positive feedback mechanisms are those where the action resulted goes in the same direction as the condition that caused it, in which case they have an incentive effect, amplifying the actions that they may determine within the system.

Negative feedback mechanisms are those mechanisms where the action resulted opposes to the conditions that caused it; when they have stabilizing effects, of balancing and maintaining the system integrity in relation to its environment.

Feedback mechanisms have an important role in all complex system. By returning a part of the output back to the system it is achieved an adjustment mechanism. The adjustment is based on the two types of feedback.

The feedback formalization

Let us consider, (X) the input into system and (Y) represents the system output, and f a function which convert input into output, then y = f(x).

We define the gap analyzer which will compare the effective value of output (ye) with expected output value (ya).

We define λ= | ye-ya| as the size of the expected output oscillation and ¶ its threshold value.

In this situation, we will have:

- If λ≤ ¶, then output value does not change;
- If λ> ¶, then the input value changes.

If λ> ¶ the next cycle of the system changes through a feedback reaction.

Thus, we can write the following formal relations that describe the process:

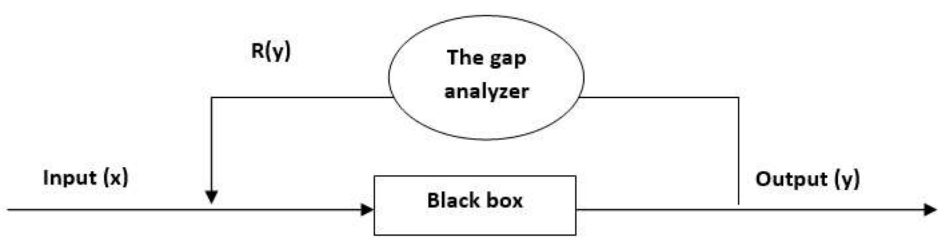
X in the following cycle: X = X + DX

Y in the following cycle: Y = f (X + DX)

We will compare the effective with the expected value of output. Based on this comparison result we'll decide to modify the cause with a size adjuster, R (Y).[1]

[1] Dinga,E., Studii de Economie. Contribuții de analiză logică, epistemologică și metodologică, Editura Economică, 2009, p.107 –an adapted figure

Figure 2. The inverse connection – general representation



There are two types of inverse connection:

The positive inverse connection amplifies the deviations of the actual effect from that expected, leading to destabilization of the system. The negative inverse connection reduces the mentioned deviation, leading to stabilization of the system. [2]

The gap effect represents an absolute difference between the effective value of a variable and the expected value of this variable. [3]

2.2. From feedback to resilience. A simple formalism

We will define the following concepts:

- System behavior represents the relationship between the system and the environment;
- System functionality is the relationship between system elements;
- Perturbations represent the environmental influences on system.

[2] Dinga,E., Studii de Economie. Contribuții de analiză logică, epistemologică și metodologică, Editura Economică, 2009, p.107

[3] Dinga, E., Asupra modelării macroeconomice. Aspecte metodologice,OEconomica, 2007, p.11

If we consider the resilience case, we will be interested in the reaction neutralization of the system; we do not care system destabilization. Thus, we consider the case of negative feedback.

If (X) is the input into the system and (Y) represents the system output and f, an transformation operator and Π – the perturbation which is acting on the system. Then, the perturbation will transforms the operator f into f '(f' ≠ f).

If we consider, f = f (x1 ... xi ... .xn, αi α1 ... ... αn), if a perturbation is acting on the system, is enough that only one variable xi 'to be different from xi and only one parameter αi' is different from αi, then the operator f is changed into f' :

f = f '(x1 ... xi' ... .xn, αi α1 ... '... αn).

Exemplification

For instance, we will use the Cobb Douglas production function:

We will consider as inputs for the production function:

- The amount of labor used in the production process, noted by L;

- The amount of capital, noted by K;

And output: production value, noted by Y;

- Coefficient of proportionality between factors, noted by A;

- Elasticity of production according to capital, noted by α;

- Elasticity of production according to work, noted by β.

Y = A * Kα*Lβ

To highlight how the external perturbations affect the capital, we will use the example of Hellegatte et al. (2007) which aims to change the Cobb-Douglas production function by introducing a term Ωk; this term represents the proportion of capital by the external perturbation.

The effective capital will be K= Ωk, * K0 , where K0 is the potentially productive capital, in absence of external perturbation.

We will have a new level of production given by:

Y1= Ωk, * f (L,K0)= A* Ωk, * K0α*Lβ

Thus, we will have the following situation:

With this new production function, in the presence of external perturbation, an x% reduction of the productive capital reduces production by x%, and the loss in output is approximately equal to 1 / α times the loss of asset estimated using the normal production function.

Conclusion

The paper provides an original assessment of the literature in terms of defining and measuring the concept of resilience. Although, the literature has proposed several methods of measuring resilience, it still remains at a formal-theoretical level. We will continue this research, especially at the institutional level, by assessing the institutional resilience impact on the economy.

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