Structure, complexity, and intrinsic qualities

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In this commentary I discuss informally the question of whether complexity theory is a scientific paradigm shift that leads science to deal with qualitative issues. This comment discusses three main issues:

1. Is science purely formal and abstract or does it also deal with the intrinsic qualities of reality?

2. Can we adhere to reductionism or must we accept a hierarchy of sciences?

3. Is the theory of complex systems qualitative?

These three questions are closely related and are of great importance for economics and the social sciences in general. I will therefore discuss each topic separately and then try to summarize from the point of view of the economy.

1. Is science purely formal and abstract?

For many centuries, science and philosophy have at least partially overlapped. Since the days of classical Greece, philosophers have tried to investigate the nature of the world and the first scientific approaches attempted to study the intrinsic qualities of things.

A conceptual change began with Galileo Galilei who in his *Il Saggiatore*, published in 1623 claimed that the language of nature is mathematics. However, it can be argued that modern science was born in 1687 with the first publication of Isaac Newton's *Principia*. With Newton physics becomes formal, axiomatic, and abstract and stands out from philosophy. When in 1865 Clerk Maxwell formulated the theory of electromagnetism, the physical sciences were formal and axiomatic.

This formalization process culminates in the development of the Theory of Relativity and quantum mechanics. Einstein's Theory of Special Relativity of 1905 had shown that concepts such as simultaneity cannot be interpreted in intuitive terms but depend on measurement processes. The operationalism proposed by Percy Bridgman in the 1930s formalized these ideas. According to operationalism, all physical variables must be defined in terms of measurement operations.

The so-called Copenhagen interpretation of quantum mechanics, developed in the period 1925-1927 by Niels Bohr and Werner Heisemberg argues that the laws of physics are nothing more than mathematical models that connect observations. According to the Copenhagen interpretation, the laws of physics are not descriptive of an objective reality but are simply mathematical models connecting observations.

There are dissenting views. Operationalism has been criticized on the basis that physics makes use of abstractly defined variables that apply even when no measurement operation is possible. For example, very high temperatures, of the order of millions of degrees, are not measurable yet the temperature variable is still validly used.

Criticisms of the Copenhagen interpretation include the difficulty of defining what is an observation and the issues raised by various paradoxes including Bell's theorem on non-locality. Scientists-philosophers such as Bernard d'Espagnat do not accept the idea that science does not describe an objective reality independent of observation. Physicists such as Louis De Broglie and David Bohm have proposed causal and ontologically realistic interpretations of quantum mechanics.

However, no alternative interpretation of physics has found wide consensus. In practice, physicists accept the Copenhagen interpretation and accept that physics is an abstract science that leaves the problem of the nature of reality unsolved. Indeed, physicists essentially believe that the problem of reality is a metaphysical problem. Physics remains close to the positions of the Logical Positivism of the Vienna Circle (Carnap, Ayer and many others) which holds that the meaning of the terms of a language can be defined only in terms of experiences.

Accepting that the entire physical theory, including the theory of complex systems, is abstract and formal, not descriptive of an external reality, the question arises as to whether there exist other sciences whose theories deal with intrinsic qualities of reality. It is difficult to answer in a simple and unambiguous way.

Sciences such as psychology, the theory of cognition and neurophysiology certainly study mental realities that correspond to the real experience. For example, a neurophysiologist can study which areas of the brain are associated with certain experiences or certain mental abilities. A psychologist can study how certain mental events are associated or perhaps cause other mental events.

In this sense, sciences such as neurophysiology or psychology study intrinsic reality. However, all these sciences treat mental events as replicable objects. The fundamental problem of self-consciousness remains unanswered. The philosopher Thomas Nagel wrote in his article *What Is It Like to Be a Bat?* published in 1974, that, assuming there is a theoretical solution to the problem of consciousness, this solution belongs to a very distant future.

This is why the answer to the question of whether there are sciences that deal with the intrinsic qualities of reality can only be ambiguous. The true nature of mental phenomena, the only phenomena of which we have direct experience, for now escapes scientific inquiry.

2. Reductionism and complex systems

There is another critical issue related to the abstraction and axiomatization of physics. It is the problem of reductionism. Reductionism is the statement that the laws of physics are sufficient to explain the behavior of every physical reality. For example, chemistry can be explained in terms of physics, at least in principle. The reductionists think that the laws of physics are sufficient to explain every physical phenomenon. Every science is an application of physics.

Those who oppose reductionism think that the basic laws of physics alone are not sufficient to explain the behavior of complex systems. In his article *More is different* published in 1972, the physicist Philip Anderson, Nobel Prize for physics in 1977, argued that the sciences must be organized in a linear hierarchical order. Each level includes the laws of the lower levels but includes new ones.

Many authors maintain that the theory of complex systems is opposed to reductionism. It is argued that complex systems have emergent properties that cannot be explained by the basic laws of physics. It is important to clarify that opposition to reductionism does not imply the notion that the laws of physics are wrong or not applicable. Complex systems are described by variables or mathematical structures whose evolution cannot be explained only by the laws of physics. There are various reasons why this can happen.

First of all it is possible that the behavior of certain structures of a complex system cannot be computed starting from the basic components such as elementary particles. Simply put, some complex structures can be too complex to be computed in a finite time. Non-computability can be not only practical but also theoretical. It is possible, for example, that the human brain is too complex to be computable.

Another obstacle to reductionism is the synthesis of complex systems. Physics is analytical and does not include constructive processes. Even if all the structures of a complex physical system follow the laws of physics, it is possible that the basic physical laws are not sufficient to explain how some structures were formed.

These considerations apply to both human artifacts and natural complex systems. For example, an engine is a complex physical system that follows the laws of physics. However, it is possible that the process, which lasted thousands of years, which led to the engineering and construction of the engine cannot be explained by the basic laws of physics but requires additional principles.

But the problem of the synthesis of complex systems also arises for natural complex systems, such as the ecosystem. Complexity theory has introduced some simple self-organizing mechanisms. However, there is no general theory of self-organization. A general theory of self-organization should be added to the laws of physics.

One of the most debated issues in connection with reductionism is the question of whether life can be explained by the laws of physics. The behavior of any biological organism, from cells to multicellular organisms, follows the laws of physics. However, the process that led to the generation of life may not be explainable simply in terms of basic physical laws but may require additional principles.

3. Complex systems and qualitative laws?

Some authors maintain that the theory of complex systems introduces a qualitative element into science. It is argued that complex systems are made up of many interacting parts and have a structure such that, as often read, "the whole is not equal to the sum of the parts".

Frankly, it is difficult for me to understand the importance and validity of this concept. What does the “sum of the parts” mean? A complex system has a structure that eventually interacts with other structures. The laws and the dynamics of these interactions depend on the structure.

For example, an engine is a complex system with a structure responsible for its behavior. It makes no sense to say that an engine is the sum of its atoms or subatomic particles. An engine is a structured set of fundamental elements. This seems a rather trivial and obvious observation. When the engine is placed in a car body, a car is obtained. Again, a car is not the sum of an engine and a body, it is a complex structure formed by these two components, which in turn are complex and interact.

It seems possible to conclude that a complex system has a structure and that the structure is a characterizing element of a complex system. The structures follow dynamics that are peculiar to each structure. The qualitative aspect of complex systems is given by the behavior of the structures.

Perhaps in some cases it could be argued that structures have a purpose, an objective. However the definition of goals and objectives is always doubtful as it is linked to an anthropomorphic vision. For example, a car is a complex artifact that has a purpose. But it is difficult to believe that the purpose of a car can enter into its scientific description.

Biological systems are often described in teleological terms, noting that this or that component serves a certain purpose. These descriptions, however, are illustrations for the benefit of human observers and could be replaced by non-teleological descriptions.

In conclusion, complex systems are characterized by the dynamics of structures. The qualitative aspects of complex systems is there structure.

4. Economics and complex systems

Modern economies are complex systems with complicated structures both in terms of interactions between agents and in terms of products. The structures create a qualitative element in modern economies. Structures are not quantifiable with single numbers.

Structures introduce a qualitative element in the sense that the characteristics of products and services are generally linked to their structural complexity. For example, in mature markets such as the United States the growth of the automotive market is not linked to the number of vehicles sold but to the characteristics of the vehicles, i.e., to their complexity.

The ecological aspect of modern economies is linked to the structures of products and services. The dynamics of certain structures is sustainable, at least within time horizons important for man. Other processes, on the other hand, are not sustainable as they are based on resources subject to exhaustion or pollution problems.

There is another qualitative aspect of economies linked to the fact that economies are populated by sentient beings. In this case the qualitative assessment of an economy is linked to values such as well-being, safety and other perceived factors. This qualitative element is much more difficult to study theoretically because we do not have adequate theories to describe and evaluate the quality of emotions.