

Challenging the Sustainable Social Progress *

The President of
The Royal Academy of Economic and Financial Sciences,

Jaime Gil Auja

The Presentation held at the ceremony for granting the title of Doctor Honoris Causa of The West University of Timișoara is based on a paper which presents a synthetic view on some economic and financial issues of our times, considering especially the crisis of the last period, and mentioning a few remarkable ideas about the mentality of humankind. The author takes into consideration in a large view, regarding economy, some aspects of physics and of other fields of modern science, such as philosophy, including irreversibility of time, suitable for our full of uncertainty and complex reality, wishing to achieve goals related to solving the economic issues and to social progress.

Economic and Financial Issues of Our Times

We, the ones who already passed the maturity threshold, believe that we have gained enough experience to proclaim the important progress that occurred during **the last decade** in the process of creating a society with an evolution without precedent in our whole history.

The achievements were the result of a conglomerate of efforts made under various ways having the common factor of liberty in stability. The development of research in different fields of knowledge represents, in our opinion, one of the key elements towards which the achieved progress is headed. This progress is nowadays threatened by the occurrence of the crisis, which hits with cruelty especially the ones who are vulnerable. How did it come to this situation and which are the methods that the economic research would propose to reduce in time and depth the consequences of the crisis are interesting problems for the ones involved in economy.

To clarify these questions some ideas regarding the

fundamental changes that occurred in the last decades in the economic structure of the West-European countries, through the transfer of the industrial activity in other developing countries, might be useful, of primarily importance being what could be called „ the tertiary system of the economy”.

It would be premature to present the conclusions of the relationship between the productive structure, on one side, and the intensity of the **economic crisis**, on the other. As a first step, it would be necessary to carefully evaluate the general impact. Only then would it be effective to elaborate an industrial plan necessary not only nationally, but especially at European level. Given the technological heterogeneity between sectors, in addressing such a process a divided analysis by sector, size and type of company activity is also necessary. Let's not forget that technical and innovative progress in industry leads to an increasing productivity in the concerned sector.

On the other hand, we should emphasize the diversity of industry in European countries with similar income level and consumption structure.

*Spanish to Romanian translation: Lector dr. Raluca Vilceanu
Romanian to English translation: Lect. Dr. Monica Boldea
TJE processing: Prof. Alexandru Jivan

Let us remember that, for example, in Germany, the manufacturing industry is twice as developed as the British, French or American one. The conclusion is clear and relevant: the countries with a high degree of industrialization show a more favorable trade balance compared with countries that have very quickly given up industrialization, regardless of market size and the degree of sectorial specialization.

These reflections, chosen from others affecting the area of industrial activity, illustrate the pre-crisis economic situation, crisis whose depth and duration are impossible to determine with precision. Currently there are no indications of how the various countries will overcome this crisis, but the sign of the ongoing discussions lead us to think that the "industrial issue" will be a main subject, both in academic discussions as well as in the government policy of countries with a high level of development. We believe that it will be talk again about the "industrial policy". But with no doubt should this comeback be used for protectionist purposes.

For the unknowing spectator, these reflections may seem marginal when we face a serious **financial crisis** at global level. Nothing could be further from the truth. Talking about the circumstances of the long term structural problems is the best way to prepare a better future. If in previous years we had faced this challenge, it could have prevented a series of disasters.

It is very true that the financial crisis overlapped and joined the economic crisis. The obvious interaction between the two crises provides an excuse for any explanation. This distorted cumulative process had not a single cause, but the use of the internal financial system became more visible and, through sophisticated and imaginative "architecture", has damaged the interconnection network of financial institutions with a high level of globalization. Contamination has been rapid and widespread.

The reality is that we realize that the crisis spectrum now covers the whole expanse of our planet, under different forms: economic, financial, political, social and moral. But these phantasmagoric occurrences may lead to a possibility of change, which has to be a **change of the system**. Indeed, we lived in an American based system, which in the past was a possibility of progress in freedom and prosperity without precedent. This cloud of prosperity has led to the phenomenon that announces the collapse of the entire human structure that meaning a country, a financial system, a society or a family:

superficiality. In this very dangerous context, the superficiality of the financial system seems a field standing on quicksand. All of this destroyed everything that had worked artificially. This was how, in a slow but relentless manner, a rupture between the economic and financial model and real economy was made. Therefore, loss of confidence of citizens in all countries was inevitable. Regaining confidence will require a major effort at educational and at dialogue level. But this is not enough. And it will remain so as long as the design of a **new cultural model** will be at stake. This cultural model must include both the new values, capable of replacing those old and now non-existent ones, and the surveillance and control systems for possible excesses in the **exercise** of freedom. This is why it is important to establish a suitable frame for freedom. The development of this **cultural model** must also respond effectively not only to the consequences of economic and financial globalization, but must take into account the shifting process towards a fraught with uncertainties and more complex society¹.

The persons engaged in research work in the field of social sciences should be interested to study economic and financial problems that occur in society. It is our duty to offer solutions that could solve or alleviate imbalances that hinder the development of the capacities of citizens, in a just and free scene.

And in this sense, today we pass through one of the most exciting moments lived by human knowledge. Those who are obliged to take decisions in any of these areas: political, social, economic and business know these facts very well. A profound meditation on how to address the issues underlying the way to achieve the common goal of mitigating the pain of those who suffer because of economic and financial imbalances is therefore required.

It is true that, increasingly, we have socioeconomic techniques able to face recessive phases of economic cycles, but this vortex of events is still increasing so that the future presents itself under a sign of **high level uncertainty**. We live in a world where events occur with unusual speed, they rush over, mix and then precipitately disappear. **Variability** is one of the most remarkable characteristics of our epoch. When we succeed, the triumph is fleeting and quickly forgotten. When we commit a mistake, when we are destined to failure,

¹ These reflections are part of the discourse which the author held at Solemn Academic Ceremony at the Royal Academy of Economics and Finance of Spain, in Bilbao, 5th February 2009.

we have to wait for another event to erase the previous one from our memory.

Efforts made during economic prosperity have been satisfactory, especially in adapting the speculative economic knowledge to the realities where the created concepts, methods and techniques created had to be used. But the inexorable force of economic events requires research to find new ways. The difficulty to use the old techniques to solve problems raised by new realities is increasingly obvious. Because realities that require adaptation are not in **an ideal world**, but in **the world surrounding us**.

A View over Scientific Activities of the Past

Why, then, this imbalance manifested repeatedly between theory and reality? We will probably find the answer in the routine of economic research, imitating physicists' questions who observe the universe. They expected to find such evidence through which they could represent the events and social phenomena. In this way, little by little, economy was coming together with the characteristic **mechanism** of physics, whose brilliant itinerary was worth all the admiration since the moment Tales of Millet (624 BC - 546 BC) raised his eyes to the sky and stated the main issues on how the cosmos works.

Mechanistic culture debris lodged during so many centuries of scientific training could not remain unnoticed in the construction of economic science. Specific economic phenomena have been studied considering the economic systems' "major mechanisms", believing, as physicists, that **differential** equations could reflect the (normal considered) behavior of agents who act on them. If the universe is governed by known laws, why should not economic systems do the same thing? Physical models that act as a clock, accepting economic systems that work as a clock. **Mechanistic** physical models, the acceptance of **mechanistic** systems in the economy.

As a result, **economics** have been based, from the beginning, on the **mechanics of movement**, which describes reversible processes where **time direction** does not play any role and there is no room for doubt.

Time reversibility in economics was one of the permanent obstacles in the development of new ways of knowledge, especially when investigating different ways in which researchers have designed

time from the formal **perspective** and its perception by economic agents in real activity. Therefore, those who have to make a decision normally associate **reality with the current moment, the past has ceases to be, and yet there is no future**. It seems that we go so far with this thought that the uncertainty of tomorrow turns into today's passing reality, which, in return, makes room for the uncertainty of the past.

But this **vital perception** is diametrically opposite to the **statement** that economics assumes the concept of time. For it, there is a "**temporal landscape**" which includes all events of the past, present and future. **Time is not moving, but objects are moving in time**. Time does not pass. It simply exists. The **time flow** is unreal, what is real is time. For the mechanicism specific for **economy**, a clock determines the **time** between events, it doesn't measure the speed it takes to move from one incident to another. So, they are **equally** accepted as **real** past, present or future events: eternity is present in all its infinite dimension.

We relax reading the work in which the correlation between **Michele Besso** and **Albert Einstein** appears. At the persistence of the first one's question "What is **time**? What is **irreversibility**?" the latter replies: "**irreversibility is an illusion**". After the death of **Besso**, Einstein wrote a letter to Besso's sister and son, a letter² containing the following words: "Michele preceded me a little in the departure from this strange world. It does not matter. For us convinced physicists, this distinction between **past, present and future** has only the value of an illusion, however persistent it may be."

Despite such strong statements, it is very difficult to accept nature without time. **Carl Rubino**³ reminds us that **Homer** in "Iliad" puts **Achilles** in a search of something **permanent and stable**, which may be obtained due to the humanity of the individual: he has to lose his life to reach this higher position. A sad lesson that Achilles learns too late. So the work relies on the issue of time. Instead, in "Odyssey"⁴, **Odises** has a choice and the opportunity lies in its ability to choose between **youth without aging and immortality** (always being Calypso's lover) and return to humanity, meaning to aging and death. He chooses **time and**

² Einstein-Besso: Correspondence 1903-1955. Edición, prólogo y notas de Pierre Speziali. Hermen. Paris 1979. Pág. 88. Traducción española para Tusquets Editores, S.A. Barcelona 1994, pags. 454-455.

³ Carl Rubino: Winged Chariots and Blak Holes: Some Reflexions on Science and Literature. Manuscrit citat de Ilya Prigogine într-o conferință susținută la Universitatea Jawaharlal Nehru, Nueva Delhi, 18 decembrie 1982, cu titlul "Doar o iluzie".

⁴ Vernant, J.P.: Le refus d'Ulysse", Le temps de reflexion III, 1982.

the destiny of people, treating the eternity and the destiny of gods with contempt. Must economics choose between the idea of a world without time and acceptance of time which seems to contradict scientific rationality? There is an incompatibility between the "**classical reasoning**" of **no time** and **our own "timed" existence**.

It is difficult to deny the validity of the terms of **past and future**, even though the inexistence of "time flow" is sustained. In economy there is a multitude of irreversible phenomena. We could say that most. In a final position, an **asymmetry of objects in time** could be accepted, even if not an **asymmetry of time**.

It is true that non-temporality is a solid basis on which to build the concept of the **duration of equilibrium**, a fundamental element of economics. But this does not exclude the initial difficulty to put together the realities of a society led by the "orthodox doctrine". An attempt is made by **Ilya Prigogine** (1917-2003) when differentiating the **equilibrium structures** and the **dissipative structures**⁵. A balance of structure does not require external flow to maintain itself, therefore any activity that generates **entropy** is prohibited. A dissipative structure cannot exist without the outside world; without external contributions that maintain dissipation, it disappears and the system reaches an equilibrium state. So, only **when there is instability**, mechanistic laws are fully respected. Could the financial situation we are going through be a convincing example?

It is strange to see how **Prigogine's** this original contribution brings us closer to the wonderful adventure that began almost 150 years ago with the publication, in 1859, of the work "**The origin of Species**". Indeed, **Darwin** combines two elements, **irreversibility** and **fluctuation**, when he claims that **fluctuations** for biological species, due to environmental selection, give birth to an **irreversible** biological evolution. The association between **fluctuations** (including the idea of luck, uncertainty) and **irreversibility** lead to self-organization of the systems with an increase in complexity.

In the field of **economy**, the **evolution** of social, economic and management institutions can be broadly pictured as a **pseudo-genetic renewal**, which occurs in the case of **national institutions** and other **public institutions**, as well as in the case of **companies**. This pseudo-genetic renewal

gives birth to **successive generations of economic systems and societies**, and makes sure that each of them has a unique structure. It is an irreversible time process that destroys the **mechanistic patterns** of the classical and neoclassical studies of economics, both loaded with non-temporality.

We are aware of the difficulties encountered in the involvement of evolutionary and irreversible models in the concerns of teachers and researchers. The problem is not a new one. **The rupture** in the economy, implying the evolutionist versus mechanical idea, gives birth to the same doubt and rejection as the Darwin theory or, alternatively, as the creativity theory in biology. Illustration for the example above is the conflict between Bishop **Samuel Wildberforce** and **Thomas Huxley** (grandfather of Aldous Huxley). It is said that, in a public speech, Wildberforce asked **Huxley** whether his **progeny of monkeys** was **maternal** or **paternal**. **Huxley** replied that he would prefer to be descendent of a monkey than of a bishop.

Using **time reversibility** and **mecanicism** in economy resulted in a **determinism** in which the notions of liberalism and freedom have been words with no meaning, when we tried to seek answers to the critical questions of economic reasoning.

Paul Valéry observes that "*meaning of the word determinism has the same degree of uncertainty as the word freedom*"⁶. This is why we mention Karl Popper's statement⁷: "*Every incident is caused by another incident, so that any incident could be predicted or explained ...*" or "*commonsense assigns healthy adults the ability to choose between different ways...*". This inner contradiction is a major problem that **William James**⁸ called "the determinism dilemma" which, if transposed into the economy, we realize that it reflects our relationship with society. Therefore, is society already created or is it in permanent development?

If for a large number of physicists, including **Einstein**, the problem of **determinism** and **time** are already solved, the philosophers still have questions. Thus, **Henri Bergson**⁹ says that "time

⁵ Prigogine, I.: La fin des certitudes. Versión española de Ed. Taurus. Buenos Aires 1997, págs. 11-12

⁶ Valéry, P.: Cahiers, I. Bibliothèque de la Pléiade. Ed. Gallimard. Paris 1973. Págs. 531-651.

⁷ Popper, K.: L' univers irrésolu. Plaidoyer pour l'indéterminisme. Ed. Hermann Paris 1984 pág. XV.

⁸ James, W.: "The Dilemma of Determinism" en The Will to Believe. Ed. Dover. New York, 1956.

⁹ Bergson, H.: « Le possible et le réel » en : Oeuvres. Presses Universitaires de France. Paris 1970, pág. 1333.

delays, or better said, time is a delay". So, it has to be prepared. As a result, isn't there a system of creation and choice? Couldn't time somehow demonstrate the fact that there is uncertainty in things? This way, for Bergson **realism** and **indeterminism** resemble. **Karl Popper** also considers that "the Laplacian determinism - which seems to be confirmed by determinism theories of physics and their success - is the main obstacle in explaining freedom, creativity and human responsibility."¹⁰

The fact that the **deterministic** idea is present in the Western mentality since the pre-socratic period causes a deep tension when wanting to encourage an **objective knowledge** and simultaneously to promote **the human ideal of freedom**. Science would come to a contradiction if it would choose a **deterministic** view when it is involved in the mission to develop a **free** society. We cannot identify **science** and **certainty**, on one hand, **ignorance** and **possibility** on the other.

The New Ways of Knowing the Complex Realities

This confirms that the research activity is at a crossroads where the future of science is at stake. On one hand, there will be **geometric view** on knowledge, on the other, a **Darwinist view**. On one side the sublime and famous songs that are renewed only in form. The dream of reducing how the world functions to the predictability of a mechanic game. On the other side, the void of the unknown. The attraction for adventure. The invitation for a leap forward guided only by the hope to open new horizons. The responses to the call of **Ludwing Boltzmann, Bertrán Russell, Lukaszewicz, Zadeh, Lorenz, Prigogine, Kaufmann**. The rejection of destiny and proclaim of **freedom of decision**.

In our incursions in the spheres of economic research, we have dedicated our academic life to the fight against **determinism** and **destiny**, helping to build technical and theoretical elements that bear **freedom**. We had the huge chance to receive some of the great skill of the creators of innovative ideas. Let us remember from our youth the teachings of François Perroux fighting against the transfer of mechanistic models in the economic environment.

Later, in the middle of the 60's, Lotfi Zadeh was the one that, with the concept of confuse assembling, will opened the doors for Arnold Kaufmann to develop and disseminate at the beginning not only some innovative techniques but a new way to orient mentalities, which are **versatile, modular and emphasizing**. Indispensable to overcome the economic determinism essences were the lessons from Ilya Prigogine, who in 1977 received the Nobel Prize for Chemistry for his contributions to thermodynamic imbalance, especially in the theory of irreversible processes.

At the International SIGEF Congress in Buenos Aires¹¹, we tried to consolidate the Epicurean position in the new coordinates, discovered by **Zadeh**¹², who stated "the principle of gradual simultaneity" (any sentence can be both true and false at the same time, provided that it grads a degree to the truth and one to the untruth). Before and after that, many scientists have founded, stone by stone, what seems be a new edifice of knowledge. But there is still need for a great deal of imagination to break the ties that keep us in the past replacing them with differential "nonlinear" equations, bearing a large descriptive arsenal of **uncertain** situations.

On the other hand, it seems that the forms that we meet in our world, both in what physical and economy-based objects are concerned, are not normally similar to the geometrical figures of the traditional mechanical mathematics. And this, despite repeated proclamation to the contrary, from the assertion of Galileo Galilei in 1610: "mathematics is the language of nature". The truth is that the geometry of nature is hard to be represented by Euclid's the usual forms through differential calculation. This often happens with the physical or mental objects of the economy. **The lack of their order** transforms them into **"chaotic"**.

Benoît Mandelbrot, in his work, *The Fractal Geometry of Nature*¹³, shows that the clouds are not spheres, mountains are not circles and the bark of a tree is not smooth. With this idea he develops a new

¹⁰Popper, K.: *L'univers irrésolu. Plaidoyer pour l'indéterminisme*. Ed. Hermann. Paris 1984, pág. 2.

¹¹Gil Aluja, J.: *Lances y desventuras del nuevo paradigma de la teoría de la decisión*. Proceedings del III Congreso de la Sociedad Internacional de Gestión y Economía Fuzzy. Buenos Aires, 10-13 noviembre 1996 (sin numerar)

¹²Zadeh, L.: *Fuzzy Sets*. Information and Control, 8, Junio 1965, Pág. 338-353.

¹³There is a Spanish translated version of the third edition of the French title "Les objets Fractals. Forms, hasard et dimension", editada en 1993 por Tusquets Editores, SA which is called "Los objetos fractales".

kind of mathematics, able to describe and study the irregular structure of natural objects. He established a name, fractalus¹⁴, to name these new geometric forms. **Fractalus**, as happens with **chaos**, are based on the **irregularity of the structure**. With both of them, geometric imagination acquires a fundamental importance. Therefore, if in **fractalus** geometry dominates, in **chaos** dynamics subordinates geometry. It might be said that **fractalus provides a new language capable of describing the form of the chaos**.

The opportunities to geometrically represent the irregular economic phenomena open the doors to fractal use in the field of social sciences. Couldn't the concern for stock fluctuations stimulate the study of this new **geometry of nature** by economists and specialists in management?

There are three fundamental axes which configure the search for a new way of looking towards economic science: **uncertainty and certainty, irregularities from the laws of nature and the complexity of linearity**.

Uncertainty, irregularity and complexity seem to be the main challenges that the movable realities raise social and economic research. It is necessary to investigate what is innermost in each of the levels of knowledge to try to find, in each of them, the key to open the gates towards an effective treatment for **uncertainty**. The **"excluded third party"** principle is opposed to the **"principle of gradual simultaneity"**. "The Boolean logic" has been generalized by a whole range of "multi-logics". "The mathematics of certainty and fortune" was completed with "The numerical and non-numerical mathematics of uncertainty." The "models and algorithms" used for over 50 years have been removed or transformed into "the blurred system theory".

The study of economic irregularities is one of the pending subjects both in research and in education. However, interesting works calm the anxiety of the researchers in this field. There have been attempts to describe the optimization of the portfolio values ties seeking for solutions through fractal geometry. There were projects to assess the most volatile dimensions of economic systems using the tools able to represent irregular structures. There is, no doubt, a long way to go until obtaining a coherent structure that can

support works that meet the formal strength and practical effectiveness.

They say the famous and beautiful phrase of **Edward Norton Lorenz** (1918-2008) "a movement of butterfly wings in Brazil can cause a tornado in Texas?" It is the most intuitive representation of **chaos**. Without underestimating the extraordinary interest of his work, we consider that what we might call the **theory of complexity** goes further and includes other aspects than the ones considered by **Lorenz**.

At the beginning of the 9th decade of the 20th century, following the elaboration of a work published together with **Arnold Kaufmann**¹⁵, we could verify the importance of those systems in which, starting from some specific data and a deterministic system, some results that didn't follow a recognizable landmark could be obtained. The behavior seemed **chaotic**. Shortly afterwards, we tried to deepen the possibilities of incorporating the chaos theory in the treatment of certain economic issues. The results were made public by publishing a book and two articles that have been widely disseminated. We thought we opened a new gate for future research. Today, in the perspective of time, we realize that **there is still a long way ahead of us**.

I would like the last words to sound like an anthem of hope. To do this, I recourse to some of Einstein's words, who he said: "creativity is born from fear, as the day is born from the night. During a crisis, inventiveness, great discoveries and strategies are born. Who exceeds the crisis exceeds itself without being exceeded. Who blames the crisis for his failure and his poverty attacks his/her own talent and respects problems more than solutions". Science must play an important role in the rules that will govern future international relations. We trust in future contributions made by the newly-opened fields of research. They must be the ones able to spread the light of science and at the same time to strengthen solidarity and welfare of all citizens. Only this way will we submit to the desired **sustainable social progress**.

¹⁴The Latin adjective "**fractus**" can be translated into "broken, irregular".

¹⁵Kaufmann, A. y Gil Aluja, J.: Nuevas técnicas para la dirección estratégica. Ed. Universidad de Barcelona. Barcelona, 1991.

Bibliography

1. Aristóteles, 1977. Obras. Lógica. De la expresión o interpretación. Ed. Aguilar, Barcelona.
2. Bergson, H., 1970. "Le possible et le réel", en Oeuvres, PUF, Edition du Centenaire, Paris.
3. Blanc, M., 1990. Les Héritiers de Darwin, Éditions du Seuil, Paris.
4. Boltzmann, L., 1872. Weitere Studien über das Wärmegleichgewicht unter Gasmoleculen, Viena, Berlin.
5. Bruno, G., 1907. "De la causa". Opera italianae, quinto dialogo I. Bari. Citado por Leclerc, I., 1972. The Nature of Physical Existence. Ed. George Allen and Urwin Ltd., Londres.
6. Clark, R.W., 1971. Einstein, the Life and Times. Avon Books.
7. Clausius, R., 1865. Ann. Phys., CXXV.
8. Dupas, A., 1977. La Lutte pour l'espace, Éditions du Seuil, Paris.
9. De Luca, A. y Termini, S., 1972. « A definition of nonprobabilistic entropy in the setting of fuzzy sets « theory », information and control, 20.
10. Einstein-Besso, 1972. Correspondence. Ed. P. Speziali, Hermen, Paris.
11. Gardner, M., 1979. The ambidextrous Universe. Charles Scribner's Sons, Nueva York.
12. Gil-Aluja, J., 1996. "Lances y desventuras del nuevo paradigma de la teoría de la decisión", en Proceedings del III Congreso SIGEF. Buenos Aires, 10-13 noviembre.
13. Gil-Aluja, J., 1998. Elements for a theory of decisions in uncertainty Kluwer A. P, Dordrecht.
14. Gil-Aluja, J., 2005. Reflexiones ante un nuevo pensamiento económico. Ed. CIDEM, Morelia.
15. Jacquard, A., 1986. L'Héritage de la liberté, Éditions du Seuil, Paris.
16. James, W., 1956. "The Dilemma of Determinism", en The Will to Believe, Dover, Nueva York.
17. Kaufmann, A., 1973. Introduction à la théorie des sous - ensembles flous à l'usage des ingénieurs. Masson, Paris.
18. Kaufman, A. y Gil-Aluja, J., 1991. Nuevas técnicas para la dirección estratégica. Ed. Universitat de Barcelona, Barcelona.
19. Lukaciewicz, J., 1910. "O zasadzie wyłączonego srodka". Przegl'd Filozoficzny, 13.
20. May, R., 1973. Model Ecosystems, Princeton University Press, Princeton.
21. Misra, B., Prigogine I., Courbage, M., 1979. "PNAS", 75.
22. Moles, A. A., 1990. Les Sciences de l'imprécis, Éditions du Seuil, Paris.
23. Perroux, F., 1969. L'économie du XX ème siècle. P. U. F. Paris.
24. Poincaré, H., 1906. La science et l'hypothèse, Flammarion, Paris.
25. Popper, K., 1984. L'univers irrésolu. Plaidoyer pour l'indéterminisme, Hermann, Paris.
26. Prigogine, I., 1947. Etude thermodynamique des phénomènes irréversibles, Desoer, Lieja.
27. Prigogine, I., 1980. From Being to Becoming, W. H. Freeman, San Francisco.
28. Prigogine, I., 1997. La fin des certitudes. Traducción española con el título El fin de las certidumbres. Ed Taurus, Buenos Aires.
29. Rosenfeld, L., 1971. « Fuzzy Groups », Journal of Mathematical Analysis and Applications, 35.
30. Rosenfeld, L., 1971. "Considérations non philosophiques sur la causalité", en Les théories de la causalité, PUF, Paris.
31. Schlanger, J., 1971. Les métaphores de l'organisme, Vrin. Paris.
32. Sugeno, M. 1977, « Fuzzy measures and fuzzy integrals, a survey », en Gupta, Saridis y Gaines.
33. Thom, R., 1977. Stabilité structurelle et morphogénèse, Benjamin, Reading, Mass.
34. Valéry, P., 1973. Cahiers I, Bibliothèque de la Pléiade. Gallimard, Paris.
35. Weimberg, S., 1977. The first three Minutes, Basic Books Inc., New York.
36. Whitehead, A.N., 1969. Process and Reality, the Free Press, Mac Millan Company, Nueva York.
37. Zadeh, L., 1965. «Fuzzy Sets» en Information and Control, 8.
38. Zadeh, L., 1996. «Fuzzy Logic and the Calculi of Fuzzy Rules and Fuzzy Graphs». International Journal of Multiple-Valued Logic, I., págs. 1-39.
39. Zimmermann, H.J., 1978. «Results of empirical studies in fuzzy set theory» en Klir, G.J.: Applied General Systems Research. Plenum Press, New York.