THE SPANISH SCHOOL OF FUZZY ECONOMICS

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The beginnings of the now flourishing "Spanish School of Economics Fuzzy" must fit into the rigors of the Spanish postwar period, a time when this country was trying to find heir place in the international scientific community after two decades of autarky and isolationism. In this context my teaching began in October 1959 having just finalized my degree studies and at the same time initiating the courses and works required for my doctorate

Those who lived and survived that dark era will recall the difficulties experienced by undergraduates when they wished to open their intellectual horizon to scientific activity taking place outside our practically closed frontiers. The dream of every young researcher was not the American universities. For a middle class family the Mecca was much closer (although still outside the possibilities of most) and that was France.

I was one of the more fortunate, thanks to a rare conjugation of circumstances that were almost unforeseeable. I had the opportunity to attend, in Grenoble, a course on *"Methods of Operations Research"* before it reached the public eye, given by Professor Arnold Kaufmann and written in conjunction with Robert Faure: "Invitation a la Recherche Operationnelle", published by Dunod in 1961.

The permanent contacts from then onwards with my teacher and friend Kaufmann were of an inestimable value. And not only from an intellectual, speculative or theoretical point of view but, also, with regards to the possibilities of using the theoretical or technical elements in order to arrive at solutions to problems that were constantly being brought to light by reality. These problems I found in my capacity as Senior Manager of the *"Sociedad de Automóviles de Turismo, S.A,* (SEAT), a job which I found was difficult to combine with my teaching and research activity.

A few years later it was precisely this teaching and research vocation which led to my abandoning of the business field in order to concentrate all my efforts in the sphere of research. However, there remained from this period a concern that would continuously appear, whenever we drew up a new model or the work of a researcher arrived in our hands: What possibilities existed for using these schemes for arriving at a solution to the economic and social problems which were becoming more and more immersed in a context of complexity and uncertainty? We were not particularly very convinced of the efficiency of these formal elements, impeccable in their formality, but, in my opinion, rather remote from the questions raised on a daily basis, from the routine of businesses and institutions. I had passed on this concern to Arnold Kaufmann a number of times with so much insistence that he considered this as *"my obsession"*.

On one particular day, the date of which I cannot specify, but it would have been in the interval [1968-1970], I received a call from Professor Kaufmann advising me textually: *7 have mailed you a work from Professor Lotfi A. Zadeh which I believe could be the solution to your*

problems". A few days later I received a photocopy of the article, *"Fuzzy Sets"*, a copy which I keep very safe, and the reading of this would totally change the direction of my modest works, at the same time giving a new sense to my teaching and research tasks carried out up to that time.

At that time practically a dream we set as our first ideal objective that our city should be the centre around which our studies, research and teaching of the *Economic and Management Systems* within the sphere of uncertainty, supported on *Fuzzy Sets* would revolve. In the meantime, Arnold Kaufmann was putting the finishing touches to what would be the first book known to us on *Fuzzy Logic* written by a single author: *"Introduction a la theorie des sous-ensembles flous"*, Published by Masson in 1973, which would be followed by a further three volumes under the same title (1973-1978), translated into Spanish, English and Russian. A few years later, in 1980, Professor Enric Trillas had his work: "Conjuntos borrosos" [Fuzzy Sets] published by Vicens.

We felt that this overall objective could be attained, to a high degree, if we acted in three directions: in teaching, in research and in the organisation, systematization, and coordination of the human groups that were interested in this new conception of economic and business studies. On this hopeful horizon, we had the great fortune of getting the enthusiastic cooperation of young professors from the Universities of Barcelona, Rovira i Virgin and Gerona, the latter two headed by the very much missed Professor Carlos Cassu and Professor Joan Carlos Ferrer in Gerona and by Professors Antonio Tercefio and Gloria Barbara in Reus-Tarragona.

We commenced the teaching crusade by organising seminars at universities and other institutions: the first given by Professor Kaufmann at the University of Barcelona, Fundacion Abad Oliba, at the headquarters of the U.B. in Reus (which would later become the Faculty of Economy and Business of the Rovira i Virgili University, to later move on to seminars at which the teaching was shared by Professor Kaufmann and myself, at the same time extending the teaching territorially to other communities: Andalucia, Galicia, the Basque Country, Extremadura, Valencia, Castilla-Leon.. Little by little research groups were formed, the presence of which at national and international congresses becomes ever more notorious. But our objective was far more ambitious: to make sure that in the teaching plans of the Universities subjects were taught with explicit "Fuzzy" contents. This became a reality at the University of Barcelona, Faculty of Economic and Business Sciences, under the following titles: "Operational Research (methods and models in uncertainty)"; "Operational Techniques for Management in Uncertainty"; "Investment in Uncertainty"; Financial Direction II (financial analysis in uncertainty)" and "Business Creativity".

The teaching of these subjects gave rise, sometime later, to the drawing up of Doctoral Theses which warranted, always, the highest consideration by the respective tribunals that judged them. We will mention as an example: "Financial Management in Uncertainty. From singular expertise to the R+expertons" (Ana Mª Gil Lafuente 1992); "Commercial management: the taking of decisions in a sphere of uncertainty" (Jordi Bachs Ferrer 1993); "Determination of the uncertainty that is inherent to commercial operations with Latin America based on the theory of fuzzy sub-sets" (Ricardo Onses 1994); "Instruments for the Analysis of Financial Operations with uncertain data" (Antonio Terceno 1995); "Numerical and non-numerical marketing in uncertainty" (Jaime Gil Lafuente 1996); "Expectations of agricultural businessmen on the price of raw materials as a basis for a model of optimization by means of the technique of Fuzzy Sets in programming" (Vicente Sanjose Mitjans 1997); "Adaptation of travel agencies to a digital sphere by means of implementing the theory of affinities" (Jordi Oiler Nogues 2000);

"Multivalent logic in the management of businesses with high risk products" (Mari Carmen Sanahuja Pi 2004). All these doctoral theses form a part of those that were directed by me during my latter years of activity at the University of Barcelona.

Later, other professors have taken up the baton. The last thesis presented in this field at the University of Barcelona, was titled: "Modelos para analisis de atributos contemplados por los clientes en una estrategia de Marketing Relacional" (Carolina Luis, December 15th 2011) and was directed by Professor Ana Mª Gil Lafuente, obtaining the maximum classification of First Class Honours "Cum Lauo'e".

The quality, dedication and enthusiasm of the research professors who have taken over allow us to visualise a splendid future for this "new" conception of economic and management studies, based on the inspired idea of "Fuzzy Sets" of Lotfi Zadeh.

Teaching can nearly always be found on the threshold of research. And if at the beginning works in the field of economy and management always carried the name of A, Kaufmann, followed by that of J. Gil-Aluja, little by little valuable works have appeared, nearly always *due* to the pen of young university professors.

From a global point of view, scientific contributions have been concentrated on the incorporation to economic research of new elements based on Fuzzy Logic, all of which *are* capable of treating complex economic phenomena. For this, a conceptual and methodological redefinition was made of the very foundations on which the instruments that were normally used for the treatment of economic realities in a context characterised by a very high degree of uncertainty were founded and from here on, a harmonious set of models and algorithms were developed. The works of Lotfi Zadeh allowed for delving into the very roots of the structure of economic thinking. The incapacity of the "principle of the excluded third" for basing valid reasoning for the study of complex economic phenomena much later led us to draw up the principle of gradual simultaneity", presented at the 1996 SIGEF Congress in Buenos Aires. This principle constituted the starting out point for the development of new logical operators which has allowed the development of important elements for the treatment of the components of subjectivity inherent to economic and management problems. The models and algorithms that were drawn up are providing important results in the treatment of the real problems of current society, where decisions are faced with new highly complex challenges.

Our first works saw the light of day, on the one hand by means of participating in Congresses, both Spanish and international, defending, on occasions not without a certain difficulty, positions that started out from the findings of Lotfi Zadeh: Mow difficult it still is to jog the minds of those who hold the "truth" of inherited science!

Little by little university companions joined forces, attracted by the possibilities of the new schemes faced by the speedy and unforeseeable changes in economic systems, people who also belonged to the most diverse schools of economy. Faced with the growing demand for giving courses and seminars, our trips to teaching and research centres on the five continents multiplied. Jointly or individually with A. Kaufmann, we travelled to 52 different countries, attempting to plant in them the seeds for carrying out new works. Just a few pieces of data are irrefutable proof of the success attained by the works of Lotfi Zadeh when they were used in the field of economy,: I have participated on the Editorial and Scientific Board of 19 economic and management reviews and have formed a part of 111 Scientific and Organisation Committees for Congresses, presiding over 49 of the same.

It would be rather extensive to list the more than 200 works published in scientific reviews and congress and conference proceedings, but we would like to dedicate a paragraph to the writing and publication of our works in book form.

The first book on management was published in Spanish in 1986 under the title of "Introducción a la teoria de los subconjuntos borrosos a la gestion de la empresa" [Introduction to the theory of fuzzy sub-sets to business management], with the signature of A. Kaufmann and J Gil-Aluja. Following this book and under the signature of both authors there were 7 other books, the last of which: "Grafos neuronales para la economia y gestión de la empresa", (1995) [Neural graphs for economy and business management], saw the light of day a year after the death of Professor Kaufmann. In the latter years of his life we had incorporated into our working team two brilliant and young professors: Antonio Terceno from the Rovira i Virgili University who joined us in the writing of the book "Matematica para la economia y gestion de empresas", (1994) [Mathematics for economy and business management] and Ana Mª Gil-Lafuente with whom we wrote the well known work "La creatividad en la gestion de empresas" (1994) [Creativity in business management] with later translations into several languages. With this our intention was to ensure our continuity, and this has been the case.

One of the fields of study which has attained the most popularity in latter years is the economic-financial management of sport. In this field of study, I published a book in fuzzy code: "Algoritmos para la excelencia. Claves para el exito en la gestion deportiva" (2002), [Algorithms for excellence. Keys to success in sports management] which has signified for the author the fact of being considered as one of the most important specialists in the world on the economy of sport (see University of Strasbourg).

The untimely death of Kaufmann required certain changes in our working teams, as well as a restructuring of the numerous tutorships of other teams. For me personally it meant carrying on alone with the tasks that for so many years we had carried out together. I have published five books, now with a greater economic content: "La gestion interactiva de los recursos humanos en la incertidumbre" (1996) [The interactive management of human resources in uncertainty]; "Invertir en la incertidumbre (1997), [Investment in uncertainty]; "Elementos para una teorfa de la decision en la incertidumbre" (1999), [Elements for a theory of decision in uncertainty]; and "Introduccion a la teorfa de la incertidumbre en la gestion de empresas" (2002), [Introduction to a theory of uncertainty in business management], the first three with a version in English published by Kluwer A.P. and the latter by Springer. Finally, a work published in Spanish: "Algoritmos para el tratamiento de fenomenos economicos complejos. Bases, desarrollos y aplicaciones (2007), [Algorithms for the treatment of complex economic phenomena. Bases, development and applications], was written in conjunction with Ana Mª Gil Lafuente and is currently being published by Springer under the title of Towards an Advanced Modelling of Complex Economic Phenomena".

Throughout so many years of work, academic and university communities have wanted to recognize the work done in the sphere of economy and management by following the path left by Lotfi Zadeh. Thus we have been honoured with 24 "Honoris Causa" Doctorates by universities on four continents and the doors have been opened for us at 11 Scientific Academies. For one of these, the Real Academia cs Ciencias Economicas y Finarcieras of Spain I was elected President, office which I have held since 2002.

With the work published as a book in 1986 we systematically incorporated the Fuzzy Sets of Lotfi Zadeh to the analysis and treatment of management problems. From this research activity new theories have arisen and the generalisation of many other existing ones has taken place. In this regard we should mention the theory of forgotten effects, the theory of affinities and the theory of expertons. On the other hand, the creation and development of the concept of the neural graph constitutes a further step for "explaining" the multiple connections of economic and management relations, which we consider as important.

A) The theory of forgotten effects came about starting out from an idea of Ramon Llull (1235-1315) and allows for the establishment of the set of relations of causality of second and higher degrees, which the human mind, in its current state, is not capable of carrying out and which on the other hand is quite possible by means of logical operators. In a first approximation we used the max-min convolution.

B) The theory of affinities constitutes a generalisation of the relations of similarity, which can be formalised by means of rectangular matrices and presented by means of lattice structures.

C) The theory of expertons, mentioned by Kaufmann in one of his works, means a profound change in the treatment of problems of aggregation, given the fact that, by means of its development, it is possible to maintain all the information which is available initially right up to the end of the process, at the same time that non-linear operations are being carried out with the added information.

Over the latter years we have dedicated our efforts to bringing to light that it is ever more difficult to base economic knowledge on the "geometric conception", with its mechanism and irreversibility. Thanks to the flexibility and adaptability of Fuzzy Sets we were able to incorporate into management studies the Darwinian idea with its components of asymmetry and irreversibility. The difference carried out by llya Prigogine between a structure of balance and a dissipative structure with its generating activity of entropy allowed us to envisage new possibilities for developing elements that were capable of better understanding the complexity of economic relations. Up until now the results have been encouraging as is shown in the last book, in which two possible lines of Fuzzyfying pre-topological and topological spaces with the object of making them suitable for the construction of algorithms capable of treating economic situations with a very high degree of uncertainty was presented.

Geographic, but also ideological dispersion in an academic sense of all, people and groups, who became incorporated into our lines of Fuzzy teaching and research required the construction of organisational structures, if what was desired was to successfully channel and give opportunities to researchers who desired the commencement of a promising scientific trajectory.

After multiple steps were taken and carefully considering the possibilities of the time, we took the decision to establish as the centre and headquarters of our activities the City of Reus, where the Faculty of Economic and Business Sciences of the Rovira i Virgili University is located The legal coverage of our scientific organisation would be provided by two institutions: an association which took the name of SIGEF (International Society for Fuzzy Management and Economy) which would organise a yearly meeting under the format of a congress and would publish a review, and a foundation (FEGI) (Foundation for the Study of Management in Uncertainty), the principal objective of which would be to obtain financial means in order to subsidise the needs of SIGEF, and at the same time would periodically grant an award in order to honour researchers within the sphere of Fuzzy Economy and Management. The presidency of

this foundation would be held by the Mayor of the City of Reus. In April 1994, toe association and foundation were set up and in the same city where they have their headquarters, Reus, on the 16-18 of November 1994 the 1st International Congress on Fuzzy Management and Economy took place.

This congress has been followed every year without interruption by congresses in different European and American cities. In 2012 the International Congress of SIGEF will once again carry out all of its activities in the place of its headquarters, in Reus.

Likewise, in 1994 The Fuzzy Economic Review was created to include scientific works, which at quarterly intervals today carries on the task of making known all those works that are considered of quality from among those who use elements of Fuzzy Logic to provide solutions to the problems that concern those responsible for economy and management at all times, both in the micro and the macro-economic world.

The FEGI foundation on the other hand, continues its task of encouraging and feeding the activities of the association. And this independently of the ups and downs of municipal policies, which mean changes in the presidency, as a consequence of the election results for the designation of the government of local entities.

In 1994, on the occasion of the sudden death of Professor Arnold Kaufmann the FEGI foundation unanimously agreed to institute the Kaufmann Award in order to recompense those scientists who stood out due to their research in the sphere of the study of economic or management systems with the use of Fuzzy Logic. The design of the medal was entrusted to the great sculptor Josep Mª Subirachs, author of the façade of the Passion of the temple of the Sagrada Familia by Gaudi (born in Reus). Subirachs accepted the task and designed and created the Kaufmann Medal, cast in gold.

Since then illustrious researchers who have worked in the sphere of economy and creating methods, models or algorithms that were useable in this field, making highly interesting scientific and/or technical contributions have been awarded the prize. Among others the following have been honoured: H.J. Zimmermann, M.M. Gupta, J. Klir and J. Kacprzyk. !n 2004, we had the honour of granting the Kaufmann Medal to Lotfi Zadeh. This year, 2012, on the occasion of the SIGEF Congress this prize will once again be awarded to a personality, at this time not designated as we are awaiting the meeting of the Jury.

It is now nearly half a century since Lotfi Zadeh published his fundamental work "Fuzzy Sets". The message contained therein continues to be alive, and, what perhaps is most important, it continues to be useful for awaking sleeping consciences, and to illuminate new paths towards a better knowledge of physical, biological and social phenomena. For those, like us, who have dedicated 56 years of our life in attempting to understand, explain and adequately treat economic and management realities, the work of Lotfi Zadeh has meant an impulse, whicn we would hope to be permanent.

These have so far been the beginnings and the first steps of "The Spanish School of Economics Fuzzy", demanding, but fruitful. We expect nothing less of those to come, because now we are more and better. And the proof is the quality of the research which I am proud to present here.

They *are* the evidence that all the effort has paid off and that the witness of fuzzy logic, science and knowledge is in the best hands to achieve a better world, a fairer, freer and more united.