Fifteen years of econophysics: worries, hopes and prospects

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Abstract This anniversary paper is an occasion to recall some of the events that shaped institutional econophysics. But in these thoughts about the evolution of econophysics in the last 15 years we also express some concerns. Our main worry concerns the relinquishment of the simplicity requirement. Ever since the groundbreaking experiments of Galileo some three centuries ago, the great successes of physicists were largely due to the fact that they were able to *decompose complex phenomena into simpler ones*. Remember that the first observation of the effects of an electrical current was made by Alessandro Volta (1745-1827) on the leg of a frog! Clearly, to make sense this observation had to be broken down into several separate effects.
Nowadays, with computers being able to handle huge amounts of data and to simulate any stochastic process no matter how complicated, there is no longer any real need for such a search for simplicity. Why should one spend time and effort trying to break up complicated phenomena when it is possible to handle them globally? On this new road there are several stumbling blocks, however. Do such global mathematical descriptions lead to a *real* understanding? Do they produce building blocks which can be used elsewhere and thus make our knowledge and comprehension to grow in a cumulative way? Should econophysics also adopt the "globalized" perspective that has been endorsed, developed and spread by the numerous "Complexity Departments" which sprang up during the last decade?

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1 Past and future

It is quite by purpose that this paper about the 15th anniversary of econophysics is more focused on the future than on the past. Of course, it will provide an insight about the beginnings of econophysics but who cares about the past unless it is a springboard for the future. The main objective of this study is to draw useful lessons from the past 15 years. Among the questions that it will address one can mention the following points.

- One of the main objectives of econophysicists was to apply to social phenomena the methodology that proved so successful in physics and chemistry. To what extent did they succeed?
- During the past 15 years, the connection between econophysicists and economists did not improve. On the contrary, the gulf between the two fields became wider. Can we understand why?
- Historically, physics and chemistry were the fruits of a search for *simplicity*. Indeed, through their ground breaking experiments Galileo and Lavoisier were able to lay down basic principles that provided sound foundations for further progress. Technical innovation, speculation about natural phenomena, astronomical observations had existed in various civilizations. But the small flower of real scientific investigation had grown only in a few places and time periods. To what extent were physicists able to emulate this process in the study of social phenomena?
- There has been a massive and worldwide trend in physics over the past decade, namely the emergence of departments focusing on "complex systems". This term includes a broad range of topics such as colloids, polymers, sandpiles, traffic jams, neural networks, colonies of social insects, stock markets, financial derivatives. The list is endless. As a matter of fact, almost any real system is complex unless one has been able to decompose it into simple components. For instance, a pendulum made of a semi-elastic chord and a mass of arbitrary shape is a complex system in the sense that it can display at least half a dozen inter-related effects some of which are non-linear, e.g. parametric resonance, Foucault effect, spatial beat effect, Puiseux effect. This is illustrated in Fig. 1.

Did this trend benefit econophysics or was it rather disruptive. Sadly, the prevailing impression is that this new soft matter physics neglected or threw away the requirement of simplicity which for centuries had been an essential beacon in physical research. We will explain why.

Before we begin this review a word of caution is in order. Obviously, in the limits of a fairly short paper it was impossible to do justice to the many books and articles which contributed to the growth of econophysics. Most of the citations will serve to illustrate specific events, attempts, trends or ideas that I wish to explain. This is a fairly personal account. I did not try to give an objective narrative and apologize in advance to all the econophysicists whose work, however important, was not explicitly mentioned.

2 The beginnings of institutional econophysics.

I tried to present an historical account of the beginnings of econophysics in an earlier publication (Roehner 2002, chapter 2). In the course of time I came to realize that it has two serious defects. The first is the fact that it is too Western-centric in the sense that major events which occurred in China, India or Japan were overlooked. The second is the fact that it does not highlight the sociological circumstances of the birth of econophysics. We will come back to these points in a short moment.

In spite of its shortcomings the historical account of 2002 nevertheless had one good feature: it made a clear distinction between pre-institutional econophysics and institutional econophysics. In its institutionalized form, econophysics came into existence when it became possible to publish papers on economic or sociological problems in *physical* journals. In the broader sense of "studies in economics done by physicists" econophysics has been in existence for a long time. Just to mention a few names,

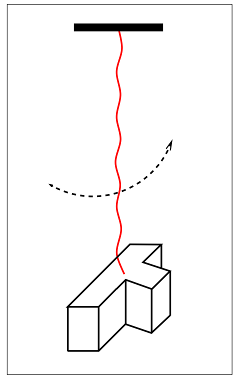

Fig. 1 A pendulum seen as a complex system. The pendulum shown here differs from a standard pendulum only because we have exaggerated some of the features which are present in all pendulums. It has a fairly elastic suspension chord, but of course no real suspension is completely inelastic. The mass is non-spherical but no real sphere is completely spherical. This pendulum shares many of the characteristics of a complex system in the sense that it is subject to several inter-connected non-linear effects and exhibits complicated (yet deterministic) trajectories. Any *global* mathematical model (however satisfactory it may be in terms of adjustment to the observations) would lead to little real understanding of the different mechanisms which are at work.
Fifty years ago it would have been impossible to study this phenomenon globally. Nowadays, the use of computers have made this possible. Even complicated trajectories can be recorded and fed into computers and even non-linear differential equations can be solved numerically and adjusted to the data through standard curve fitting softwares.
Through this example we wish to point out that if we give up trying to decompose complicated phenomena into simpler sub-modules we lose much of our ability to get a real insight. An even more serious consequence is that the models of complicated phenomena can no longer serve as basic bricks. Such complex models are just too specific to be transposed elsewhere. So we lose the ability to build science as a modular structure which grows in a cumulative way.
In short, even though computers are fantastic tools in many fields (e.g. engineering or data processing) they lead physicists to neglect the vital task of simplifying the phenomena that they wish to understand.

Alphonse Quételet (1796-1874), Léon Walras (1834-1910), Vifredo Pareto (1848-1923) or Robert Gibrat (1904-1980) were all physicists or engineers by education.

Now let us come back to the shortcomings.

- In the account of 2002 I gave a list of early conferences in econophysics which, quite unfortunately, overlooked the conferences which were held in India and in particular the 1995 Kolkata Conference which was a satellite meeting of "Statphys 19" (i.e. the 19th annual conference on statistical physics) which was held in August 1995 in Xiamen, (Fujian province, China). It is in the title of a talk given by Eugene Stanley (published in Physica A as Stanley et al. (1996)) that the neologism "econophysics" was used for the first time. For a new field it is important to have a name, otherwise how can one explain to others the kind of research one is doing. In subsequent years there have been annual conferences on econophysics in Kolkata. Entitled "Econophys-Kolkata I", the first was held at the Saha Institute of Nuclear Physics from 15 to 19 March 2005. For a rather informal field such as econophysics the regularity of these meetings is quite important and remarkable. By bringing about interactions and exchanges, these gatherings strongly contributed to the development of the new field.
- Any scientific breakthrough has also a sociological facet. In the first pages of the first chapter of "Driving forces" (2007) we describe the sociological facet of the quantum mechanics revolution which occurred in Germany around 1925. At that time, Arthur Compton, Paul Dirac, John von Neumann, Linus Pauling, Robert Oppenheimer, Edward Teller, Eugene Wigner, none of whom was Ger-

man, visited Göttingen. It is through their interaction with Born, Einstein, Heisenberg or Schrödinger that quantum mechanics was created and quickly spread to other countries. Between 1996 and 2000 a similar process was at work in Boston. Why did it not lead to a revolution of the same magnitude? The reason is very simple.

Organized versus unorganized data. In the decades before 1925 a wealth of experimental results had been produced and arranged in the form of a striking series of empirical laws which covered several fields: radioactivity and α particles, emission spectra of atoms, absorption coefficients of X-rays, and so on. In spite of several phenomenological attempts no comprehensive theory had emerged. But the data were there; they were accurate and already well organized in the form of relationships between different variables. Nothing of the sort existed in 1995 for economic or social phenomena. Of course, a lot of data were available but the data were not arranged in the form of clear relationships between variables. For instance, although big amounts of stock prices are available, these are "unorganized data" in the sense that we do not know what are the main determinants of such prices. So the time was not really ripe for a comprehensive theory.

3 An anniversary tribute to Prof. Eugene Stanley

From the very beginning there have been several "schools of thought" in econophysics, but there can be little doubt that the Boston school was the most influential. Why? Three factors can be mentioned.

- As already mentioned, for several years the group of Eugene Stanley was a kind of magnet. PhD students, postdoctoral students, visitors gathered there. There was a steady flow of seminars and at lunch-time everybody used to go to one of the restaurants just across the street. In short, through discussion and interaction this group became the cradle of something new.
- In this group Eugene Stanley held of course a prominent position, not only through a number of seminal papers (see Stanley 1995, 1996) but also because of his influence as an editor of Physica A. In this position and for over 15 years he nurtured hundreds of econophysical papers.
- As one knows, Sigmund Freud devoted a substantial amount of time and energy to keeping other conceptions than his own out of the conferences or publications which shaped the new field. So did Karl Marx. Nothing of the sort happened in econophysics. There were several schools of thought at the beginning and 15 years later they are still alive. In his position Eugene Stanley did not try to make his own preferences prevail. Thus, in spite of the fact that in his own work he was always eager to establish a close connection between data and model, completely theoretical or completely empirical papers were quite as welcome.

Moreover, in spite of the fact that econophysics started with a strong focus on finance, its scope progressively broadened. Many papers and books about economic or sociological phenomena were published in recent years, for instance on specific structural regularities in social phenomena (Wang et al. 2005, Chatterjee et al. 2007, Aoyama et al. 2010) or on the identification of social interactions (Li et al. 2010, Zeng et al. 2010). This is certainly a promising trend.

So much for history. Let us now turn to an assessment which can lead to the opening of new roads.

4 Theory versus observation

> My companion prattled away about Cremona fiddles and the difference between a Stradivarius and an Amati. "You don't seem to give much thought to the matter at hand" [the Lauriston Garden murder], I said, interrupting Holmes' musical disquisition.
> "No data yet," he answered.

> "It is a capital mistake to theorize before you have all the evidence. It biases the judgment."
>
> —Sir Arthur Conan Doyle, *A Study in Scarlet* (1886)

Physicists may not necessarily agree with the advice given by Sherlock Holmes in the citation that we put at the beginning. After all, as we know, Albert Einstein, set up his theory of gravitation, the General Relativity, purely from basic principles. At least, this is what we are told. Two remarks are in order in this respect.

- First, it is not really true that Einstein did not rely on any data. The effect of the deflection of a path of light when it is bent by the gravitational field of the sun was already known in his time (at least theoretically) for the simple reason that it is also predicted by Newtonian mechanics; the two predictions differ by a factor 2, however. Similarly, the secular change in the elliptic orbit of Mercury was well known from astronomical observations since the mid-19th century. These observations were accounted for even by the earliest versions of the theory. In other words, it is highly plausible that Einstein had an eye on such data during the time he was setting up his theory.

- There is an essential difference between physics at the beginning of the 20th century and the social sciences at the beginning of the 21th century. In 1915, physics was already built on solid foundations. Any new model or theory had to be consistent with basic physical principles (e.g. conservation of energy and angular momentum, laws of reflection or refraction, etc.). On the contrary, to my best knowledge in the social sciences there is not a single well-accepted principle, by which I mean one which can be tested by observation with a precision better than, say, 10%. Therefore, it is hardly an exaggeration to say that for any social phenomenon there are as many models as there are researches. For instance at econophysics conferences a wide range of stock market models have been proposed. All are able to explain basic characteristics of price fluctuations but as they do not propose testable predictions it is impossible to discriminate between them. The inescapable conclusion is that this is not the kind of science found in physics. The ability to discriminate between different theories is a crucial element in any science.

5 Need of a scientific revolution in the social sciences

In a recent paper Jean-Philippe Bouchaud (2008) calls for a scientific revolution in economics. He observes that economics relies on a set of axioms which, in marked contrast with the principles of physics, have never been really tested by observation. He cites the opinion shared by many economists that "these concepts are so strong that they supersede any empirical observation"[1]. He observes that during the past decades the market has been "deified" (Nelson 2002). The fact that actual achievements of economics have been pathetic and disappointing was acknowledged by many prominent economists, see for instance Schumpeter (1933), Leontief (1982, 1993), Summers (1991), Krugman (2009). What was the rationale and purpose of the "market deification"? Bouchaud points out that "the supposed perfect efficacy of a free market stems from economic work done in the 1950s and 1960s, which with hindsight looks more like propaganda against communism than plausible science."

However true, Bouchaud's view is perhaps too narrow.

[1] Incidentally, a few years ago I got exactly the same answer to a question that I was naive enough to raise while attending a course in international macro-economics.

5.1 The trend toward neoliberal economics

As a matter of fact, the target was broader than just communism. A vigorous campaign against Roosevelt's New Deal conceptions based on social solidarity was orchestrated by the National Association of Manufacturers even before the end of World War II. Some of its earliest steps were the following.

- Worldwide diffusion of a book by Friedrich Hayek (1944). Within one year after its publication simultaneously in Britain and the United States, the book was translated in Spanish, Swedish, French, Danish. A cartoon version was published in 1945 by *Look Magazine*.
- Creation of the Mont Pélerin Society in April 1947. That this meeting was aimed at being a public relations event and not just the creation of a new scientific society is attested by the fact that among the 39 persons who attended there were 4 journalists[2] .

It makes sense to think that such public relations paved the way for the economic conceptions that became later known as the neoliberal agenda.

The attribution of many Nobel prizes in economics to this current also played a powerful role. Among Nobel laureates there have been 5 former presidents of the Mont Pélerin Society[3] and (at least) 3 prominent members of this society[4]. Furthermore, Erik Lundberg who, for many years, was chairman of the Nobel Committee was also a distinguished member of the Mont Pélerin Society. For more details see Roehner (2007, chapter 6). .

5.2 Econophysicists seen as dissidents

If for a moment we admit the thesis set forward by Robert Nelson (2002) according to which the field of economics is more a religion and an ideology than a science, we can perhaps better understand the critical attitude manifested by many economists against econophysics

Let me mention a personal anecdote in this respect. In the fall of 1998 I was a visiting scholar at the Harvard Department of Economics. At some point during a conversation with my host, Samuel Williamson, I mentioned that at Boston University, that is to say a few kilometers away, there was a group of econophysicists led by Eugene Stanley who was doing path breaking research. My remark did not attract the slightest attention. It is true that some days later a member of this group, namely Luis Amaral, came to the department to give a talk. But it was a fairly confidential seminar which was not attended by any of the main luminaries of the department.

Why are econophysicists seen as dissenters, dissidents or competitors who do not play by the rules?

- As econophysicists can publish their research in physical journals, they are not subject to the rigid (and fairly arbitrary) control exercised by the referees of economic journals.
- Most econophysicists do not take the main axioms (or beliefs in Nelson's interpretation) of economics for granted. Through their insistence on confrontation with observations and testable predictions, they clearly try to transform economics into a real science. Of course, in any religion priests would feel threatened by such an undertaking.
- The mathematisation of economics which was undertaken in the 1960s provided a convenient cover. It contributed to convince the general public of the truthfulness of the underlying framework. "If it is expressed in mathematical formulas and theorems it must be scientific, isn't it?". Because

[2] The magazines and newspapers which were represented were the *Reader's Digest*, *Fortune Magazine*, *Time and Tide* (a British, Christian oriented, magazine), and the *New York Times*.

[3] F. Hayek (1961, 1974), M. Friedman (1972, 1976), G. Stigler (1978, 1982), J. Buchanan (1986, 1986), G. Becker (1992, 1992); the years within parenthesis correspond to the end of the terms as president and to the Nobel prize respectively.

[4] M. Allais (1988), R. Coase (1991), V. Smith (2002).

physicists know as much mathematics as the economists who write in "Econometrica" (or in other journals of mathematical economics), they are hardly as impressed as the general public. They know that any theory, however elegant and appealing, must be tested. As far as I know, no Nobel prize in physics has ever been attributed to a physicist for an untested theory. In contrast, many Nobel prizes in economics have been awarded for untested theoretical researches[5].

The fact that economists do not really wish to have an honest dialog is exemplified by the response made to Bouchaud's paper by an economist of Gothenburg University (Stage 2008). He claims that unemployment rates of the order of 12% were fairly common some 50 years ago. As far as I know, this is simply not true.

5.3 Impact of Bouchaud's paper

Somewhat sadly, Jean-Philippe Bouchaud concludes his assessment by the following observation. "Although numerous physicists have been recruited by financial institutions over the past few decades, they seem to have forgotten the methodology of the natural sciences as they absorbed and regurgitated the existing economic lore." This remark clearly addresses what is perhaps the main challenge to which econophysics is confronted.

Bouchaud's paper was written and published in October 2008 that is to say at the height of the financial panic. Almost two years have passed. The panic has been countered by massive injections of public money, not only to bail out failing financial institutions but also to buy those toxic assets (e.g. over-the-counter derivatives) that were spurned by investment funds. Nevertheless, the axioms of the primacy of the market and of the rationality of agents have hardly been questioned. Would such a critical paper have been welcomed in "Nature" prior to the crash and what impact did it left after the crash? Between November 2008 and March 2010 three articles were published in "Nature" which discuss or mention Bouchaud's paper. The first one by Jesper Stage (3 December 2008) was already mentioned above, the second by Hervé Philippe (7 January 2009) is a response to Stage; it weighs our present economic growth in the perspective of the long term availability of mineral resources. Finally in November 2009 there was a paper by staff writer Mark Buchanan which, in contrast to Bouchaud's emphasis on the need for empirical research and more model-testing, discusses a new (yet unproven) class of models.

6 The big player issue

"Undue or unconsidered respect for authority is a prison with invisible walls."

—Aoyama et al. (2010, Prologue),

In the economic, social and political worlds there are so-called *big players*[6]. By this expression we mean big corporations, big investment funds, influential media corporations powerful government organizations, and in a general way all groups which can have a substantial effect at macro-level whether in the economic, political or social sphere.

Because many econophysicists come from statistical physics they are reluctant to recognize the role of big players. I would suspect that during the past 15 years the inability or unwillingness of econophysicists to recognize the role of big players has hampered their understanding of many financial,

[5] Allais, Arrow, Debreu, Samuelson come to my mind in this respect but the actual list is probably much longer. In fact, very few Nobel prizes were awarded for observational research.

[6] Also referred to as *macro-players* in the context of stock markets.(see Roehner (2006)

economic or social phenomena. The parallel in physics would be to ignore external forces and treat all systems as being isolated and solely subject to endogenous interactions. Obviously, such an attitude would lead to serious blunders. That is why this point deserves careful attention.

Whereas in a crystal or a liquid individual molecules cannot bring about macroscopic changes, the physical notion of external factor nevertheless provides a close parallel to the concept of macro-player. For instance, a fairly small voltage at the gate of a field-effect transistor can control a substantial current between source and drain. An econophysicist who makes the choice of ignoring big players will be in the same position as a physicist who would try to explain the movement of electrons in a transistor without taking into account the effect of the voltage applied to its gate.

If, just for the purpose of making this argument somewhat more concrete, one wishes to get an idea of the power of government organizations here is a little experiment that can easily be performed on the Internet.

Distribution of films: a case-study. It turns out that a recent movie entitled "Ghost writer" by Roman Polanski which portrays the hidden influence (whether hypothetical or real is irrelevant in the present argument) of the US State Department on British policy had a very limited distribution in spite of being an excellent thriller as attested by the fact that it received the Silver Bear award at the Berlin International Film Festival in February 2010.
According to the Mojo Box Office website it was screened in only 5 countries, namely Austria, France, Germany, Poland and the United States. The fact that in the US it was shown in only 14 theaters during the opening week (compared with over 2,000 theaters for a standard Hollywood movie [7]) suggests that very few American people were in fact able to watch it. The movie got a good reception and wide audience in all European countries where it was shown. Yet, quite amazingly, up to now (4 April 2010) it has not been released in Britain. I was told by an English colleague that the release may occur after the general elections of 6 May 2010. This will be an interesting test.

As an additional observation it can be added that the novel by Robert Harris on which the movie is based was so far translated into 10 languages[8]. Usually, according to the publisher, Robert Harris' best-sellers are translated in up to 30 languages.

Needless to say, this is a fairly elusive issue because the US State Department will never admit that it took any action to curb the screening of the movie. On the contrary, such allegations would be dismissed as being pure fabrication. Nevertheless, careful scientists and historians will not necessarily take such denials at face value.

Role of investment funds in overnight stock crashes. A similar problem occurs when the price of a stock falls by some 20% overnight, as happened for instance for Ebay shares in late January 2005. In such cases it is very difficult, if not altogether impossible, to know who among of the big share holders has dumped millions of shares. Yet, it is very unlikely that changes which occur in such a short time can be the result of the spread of a panic among small stock holders. Through the reports issued by the Security and Exchange Commission it is possible to know the percentages held by major stock holders[9]. Unfortunately, such reports are only published every quarter which makes any precise identification impossible.

A case illustrating the power of the media. As a last example of the role of big players, one can mention the influence of mass media. This is illustrated in Fig. 2 by the specific case of media

[7] As a matter of comparison, the film "Green zone" on the occupation of Iraq seen from the American side which was released almost the same week as "Ghost writer" opened in 3,002 theaters across the United States.

[8] Chinese (2009), Danish, Finnish, Flemish, French (2007), German (2007), Italian (2007), Japanese (2009), Spanish, Swedish.

[9] Such data are also listed on the Yahoo finance website.

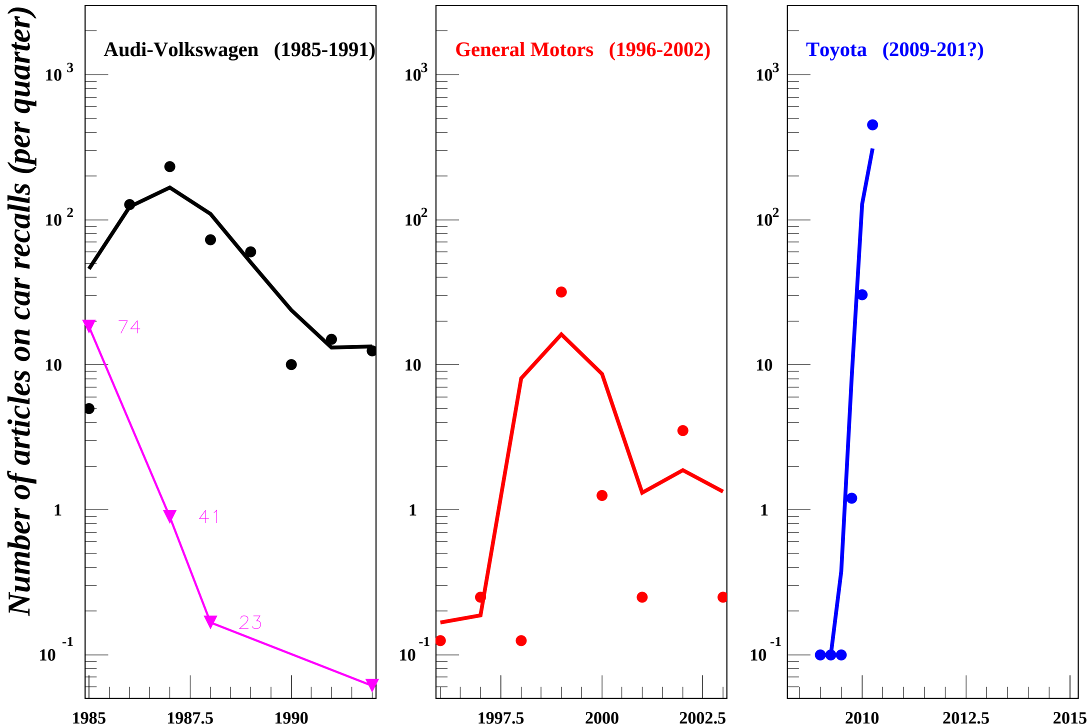

Fig. 2 Illustration of the power of US media, seen as a particular instance of the power of big players. The graph documents the action of the US press (newspapers and magazine) in three recalls of cars. The interesting point is that in terms of number of articles published these actions differed by several orders of magnitude.
In the Audi case the real start of the campaign came with a CBS program on "60 Minutes" (November 1986). In particular, it showed the tragic case of a mother whose Audi car had run over her son, allegedly because of a sudden and unexpected acceleration. However, in March 1989 a ruling of the "National Highway Traffic Administration" stated that there was nothing wrong technically with Audi cars and attributed this (and similar) accidents to mistakes made by drivers. Nevertheless, due to the media campaign, the sales of Audi cars in the United States fell from 74,000 in 1985 to 23,000 in 1989 and 12,000 in 1992 (magenta curve with numbers expressed in thousands of cars sold).
In the Toyota case, US sales have begun to plunge in early 2010 but it is still too early to say how much and for how long they will eventually fall.
From a methodological perspective the main point is that it would be absurd and pointless to forget the exogenous forces and study the spread of this "rumor" as being a spontaneous process like the diffusion of molecules in a liquid.
Sources: The information about the ruling of the National Highway Traffic Administration and about Audi sales is from the New York Times (11 March 1989 and 18 April 1993). The frequency data about the numbers of articles were obtained from a newspaper data base (Factiva) through key-word searches. We used the following key-words: "Audi+recall+acceleration", "Chevrolet+recall+tank", "Toyota+recall+acceleration". The numbers have been normalized to take into account the fact that the coverage provided by the data base became more systematic in the course of time.

campaigns on the occasion of car recalls by automobile companies.

Here again the management of TV channels or newspapers would deny any allegation concerning the very existence of such campaigns. They would say that media outlets simply reflected the concerns of the public. Yet, how can one understand that the American public should feel more concerned about a few fatal cases (allegedly) due to unexpected accelerations than about the 13,580 people who died in vehicle fires between 1981 and 2001 of which a substantial proportion was caused by faulty gas tank design and gave rise to law suits against General Motors[10]?

In short, ignoring the intervention of big players makes us unable to account for many important social effects. In physical experiments it is possible to minimize exogenous forces. In social phenomena unless such forces are identified and estimated, it makes little sense to study endogenous effects.

7 An agenda for the next decades

In order for econophysics to develop in a cumulative way, the following tasks may be of importance.

7.1 Measuring social interactions

Many economic phenomena in fact are rather social effects. For instance, when a fashion or a panic spreads like wildfire this phenomenon has little to do with micro- or macro-economics but is rather conditioned by the nature and strength of the social links between agents. Therefore we must learn how to measure these social interactions.

7.2 User friendly databases

Sherlock Holmes had an encyclopedic knowledge of the annals of crime in European countries as well as in America. For each case he was able to cite a dozen *similar* cases that had occurred in the last century. In "The Valley of Fear" (1915) he observes that "if you have all the details of a thousand cases at your finger ends, it is odd if you can't unravel the thousand and first." We should do the same. For instance, let us create a data base for real estate price crashes or credit crunches (often the two occur together)[11]. Apart from price series, such a data base should also include sale volumes, information about changes in tax regulation or interest rates. Apart from data on residential real estate it should also include data on office and commercial real estate.
Other phenomena for which it would be of interest to establish comparative data bases are mentioned in Roehner (1997, p. 20-23).

7.3 Taking into account the role of big players

Develop our knowledge of the actions of big players. Thanks to the Internet, this has now become possible in many cases as illustrated above.

7.4 A nice research field for econophysics: demography

Demographical problems are certainly "simpler" [12] than stock markets but at first sight it might seem that there are no challenging questions in demographical phenomena. This is not true. As a matter of fact, we still do not understand the determinants of many effects. For instance, predictions of fertility

[10]The source of this figure is a 2002 report of the "National Fire Protection Association" cited in "When motorists get burned", Factiva database, 1 April 2002.

[11]According to a review published on the economic history website eh.net, a recent book by Reinhart and Rogoff (2009) seems to fulfill such a program, at least partially. I have not yet seen the book itself however.

[12]It would be possible to give to this notion a more precise definition in terms of diversity of agents and interactions, range of time scales, frequency of endogenous and exogenous shocks, and so on.

rates one decade ahead in time made by American demographers of the Department of the Census in 1950, 1955, 1962, 1972 consistently turned out to be wrong by wide margins between 50% and 100% (see Roehner 2004b, Fig. 9.2 p. 328). Another example of mystery is the huge death rate (several times higher than the death rate of married males of same age) of young widowers. The younger the widowers, the larger the difference (Roehner 2007, p. 194).

For physicists demography has two nice features: (i) There are a lot of accurate data (ii) Basic demographic phenomena are a good field for comparative analysis across different countries and time periods.

7.5 Model testing

For a majority of the physicists with whom I have been able to discuss it seems clear that it is the testing procedure of models which must be improved if we wish to converge toward some basic underlying principles. The key-question is how such tests should be conducted.

First of all, it can be observed that the very existence of econophysics led to a notable improvement in this respect. Many predictions have been proposed by econophysicists during the past 15 years especially for real estate prices and stock market prices, see for instance: Roehner (2001, p. 176), Sornette (2003, p. 373), Roehner (2004a, p. 115), Roehner (2006, p. 179), Richmond (2007, p. 286).

On the contrary, economists do not usually offer predictions. We do not include in this assessment the short-term predictions made by macro-economists working for governmental statistical agencies. Of course, if nothing new happens the econometric equations which were able to describe the economy during the last semester may also hold for the next. But this is just an exercise in parameter adjustment and extrapolation, it does not reveal an understanding of specific mechanisms.

In physics the most important class of predictions are not predictions in the course of time. Of course, astronomers can predict eclipses or planet positions a few decades ahead in time but such predictions are successful only because the level of noise is low enough. This is illustrated by the case of meteorology. Although the phenomena which take place in the atmosphere are well-known physical effects, weather forecasting remains difficult. This is not because we do not understand the underlying phenomena, but because there is a higher level of noise. Similarly, in most social systems there is a high level of noise; so, even independently of inherently chaotic effects, forecasts will be difficult and unreliable.

In physics the most common form of predictions consist in what can be called "structural" predictions. For instance, once one has understood the mechanism of the Foucault pendulum and once this understanding has been tested in a few places, it becomes possible to predict what will be the behavior of a Foucault pendulum anywhere else whether in Rome (i.e. far from the Equator), in Thanjavur (Tamil Nadu, i.e. near the Equator) or in Sydney (i.e. beyond the Equator in the southern hemisphere).

At this point one should devote some attention to what is really meant by the expression "Foucault pendulum". This brings us to a point which may be very important for the future of econophysics.

8 The Pareto filtration method in physics and economics

Clearly, a Foucault pendulum is a pendulum which displays the Foucault effect. This, however, is a very small effect which can be over-ridden by several others.

- For instance if the mass of the pendulum is not perfectly spherical (and it never is, of course) this will produce a rotation of the pendulum's oscillation plane which has nothing to do with the

Foucault effect.

- If the length of the pendulum is too small the rotation of its oscillation plane will be strongly affected by the so-called Puiseux effect[13].

How do experimental physicists get rid of such unwelcome phenomena? The answer is very simple. *Physicists build their experimental devices in a way which will filter out spurious effects. Should we not try to do the same for economic and social phenomena?*

What does this mean in practice? Before discussing this method for social phenomena, it must be emphasized that even in the natural sciences this is a challenging task. This can be illustrated by the following example.
In 1907 an Americal medical doctor, Dr. Duncan MacDougall, weighted six patients about to die from tuberculosis just before their death and after their death. He found that on average they were 21g lighter after their death[14]. Naturally, before one can admit MacDougall's interpretation according to which the 21g might represent the weight of the departing soul, one must eliminate all other possible factors such as transpiration or a change in the volume of air contained in the body. After a careful discussion MacDougall concludes that these factors cannot account for the 21g difference. This is of course obvious for the air because it would represent a volume of 17 liters. In addition MacDougall conducted similar experiments on dogs and found no difference in weight.

This may seem a weird example but it clearly shows that the task is not an easy one. Often the only way to get a real answer is to perform additional experiments. For some unknown reason Dr. MacDougall did not repeat his experiment on humans, so we may never know the real answer.

Next we illustrate the filtration procedure through an example in economics. Suppose we study *speculative* real estate price peaks. As a first, step we would collect as many housing price series as possible that have sharp price increases, say a doubling over a period of 4 years. Some of these series will correspond to the phenomenon that we wish to study while others may be due to a different effect. For instance, once a new industry is established in a country town this will lead to its expansion and also probably to a substantial rise in rents and house prices. Basically this process is different from a speculative process (athough there can be a speculative component). Thus, if we wish to focus on a well-defined phenomenon such outliers must be discarded. Vilfredo Pareto (1919) was one of the first sociologists to advocate such a filtration procedure and to use it in a systematic way (Pareto 1919).

Every time I tried to convince economists that it was important to use a sound filtration method they argued that this was a completely arbitrary procedure. They did not realize that the success of physics over the last three centuries largely relied on such filtration methodologies. They allowed physicists to study one effect at a time instead of dealing with multifactorial phenomena in which everything is mixed up.

Of course, I am ready to recognize that this procedure is more difficult to implement for social phenomena than it is in physics. This is mainly because in order to change the circumstances of an observation one must find real episodes in which the new conditions are realized. Even though this may not be an easy road, I do not know of any other way to get to the *core of a phenomenon*[15]. Pareto used this methodology with success. This should be a strong encouragement. The Coriolis effect, the Foucault effect, the Puiseux effect (and indeed all physical laws) are basic building blocks which,

[13] The formula discovered by Puiseux (1820-1883) says that: $f_p = [3/(16\pi^2)](S/L^2)f$ where f is the frequency of the pendulum, L its length, S the area of its semi-elliptic trajectory and f_p the frequency with which this semi-ellipse revolves around its center.

[14] MacDougall's paper was published in the "Journal of the American Society for Psychical Research", May 1907 (the full text is available on the Internet) and his experiments were described in the New York Times of 11 March 1907 (p. 5).

[15] Pareto calls this core the "residue". This word refers to the operation of filtration in chemistry. The residue is the (useful) solid component which remains at the bottom of the filter.

once identified and well understood, can be used to develop physics in a modular and cumulative way. Personally, I am convinced that similarly there are basic building blocks in social phenomena.

During the past 15 years "Complex systems" groups were set up in many physics departments. If the acknowledged purpose of a research group is to study *complex* systems, why indeed should the researchers bother to devote time and effort to make them simpler? One should perhaps not generalize from a few cases, but I often got the impression that such complex systems are investigated by using sophisticated devices which produce large amounts of data but that the later do not lead to a clear understanding of the mechanism at work.

As one knows, the Santa Fe Institute was one of the first institutions to start this trend. Its motto, which is printed on the sweaters sold in the lobby of the institute, says: "From simplicity to complexity". When I stayed there for a few months in 2002 I tried to explain why I would be more happy with a motto saying: "From complexity to simplicity". I am not sure that my remark was well understood.

I must confess that sometimes during the past 10 years, especially while attending "Complex Networks" conferences[16], I have been feeling like a swimmer who tries to swim upstream but is inexorably dragged in the opposite direction by the strong current.

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[This article marks the beginning of institutional econophysics in the sense that, along with an article by Hideki Takayasu et al. (see below), it was accepted in Physica A by editor Eugene Stanley with the deliberate purpose of starting a new field of application for statistical mechanics.]

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[16] One should remember that at such conferences about 75% of the lectures are theoretical papers without any connection with real observations.

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This is the French translation of "Trattato di sociologia generale" (1916).
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The book was republished in 1869 but it seems that it had never been translated into English. A possible translation of the title would read: "Physics of social phenomena. An essay on human development."

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[The four references which follow are examples of early attempts in what became later known as econophysics. As a matter of fact, there have been other similar attempts made by physicists; see for instance Montroll and Badger (1974) or Weidlich and Haag (1983). In contrast with the institutional phase of econophysics which came later, these papers were not published in physical journals.]

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[The paper contains the following concluding expectation. "It may be that as we study economies less regulated or more regulated we will find as rich a phenomenology as was discovered to describe the various universality classes in critical phenomena. And it may be that theoretical models to explain our empirical findings will be forthcoming."]

[In subsequent years (as is attested by their numbers of citations) the two following articles became two reference-pillars of the new field of econophysics.]

Stanley (M.H.R.), Amaral (L.A.N.), Buldyrev (S.V.), Halvin (S.), Leschhorn (H.), Maass (P.), Salinger (M.A.), Stanley (H.E.) 1996: Scaling behavior in the growth of companies. Nature 379, 804-806,

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[This is a rare instance of a paper written by a renowned economist who is highly critical of the actual achievements of econometrics.]

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[This paper was one of the first econophysical papers ever published in Physica. It contains the following prophetic statement: "Statistical physics and economics have only little connection so far but we think their potential intersection should be very large because in both fields the main theme is to clarify the behavior of macroscopic variables in systems where a great number of microscopic agents are interacting". Of course, such a statement also applies to sociology or political science.]

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