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ARTICLE

Econophysics: Challenges and Promises — An Observation-based Approach

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Abstract

This paper tries to answer a basic (and often-asked) question about econophysics: "Whereas it is quite understandable that physical techniques of observation (e.g., infra-red spectroscopy) can be useful in investigating DNA or proteins, it is much less obvious why and how ideas from physics can be helpful in investigating socio-economic phenomena". The main obstacle to the understanding of social phenomena is the fact that they are multi-faceted, which makes it difficult to observe one effect at a time. In this paper we argue that in its early phase of development physics was confronted with the same difficulty and that the basic methodology of experimental physics has been set up precisely as a way to disentangle multi-faceted phenomena. In order to make this point, we first explain how this can be done for a very simple phenomenon, namely, the free fall. In this case, even though there are only two effects, namely, gravitation and drag, their combination can give rise to quite complicated motions. In the second part we show how the same methodology can be used to resolve social phenomena into simple mechanisms. As an illustration we consider the phenomenon of suicide and explain how it is possible to focus on *one* factor at a time. As a case in point, we investigate the suicide rate of unmarried versus married persons; it turns out that the population of Chinese immigrants in the United States provides an ideal "laboratory" for observing this effect. In a general way, in this approach the crucial question is to find a situation in which the impact of the factor under study is amplified as much as possible. In its concluding part the paper briefly discusses how the usefulness of mathematical models can be improved.

Keywords: econophysics, free fall, suicide, observation, experiment, noise reduction, multi-factor phenomena, modeling, prediction, models.

1. Introduction

Nowadays physics has become a very formalized and theoretical field. Historically, however, this is a fairly recent situation. The graph in Fig. 1 suggests that this evolution

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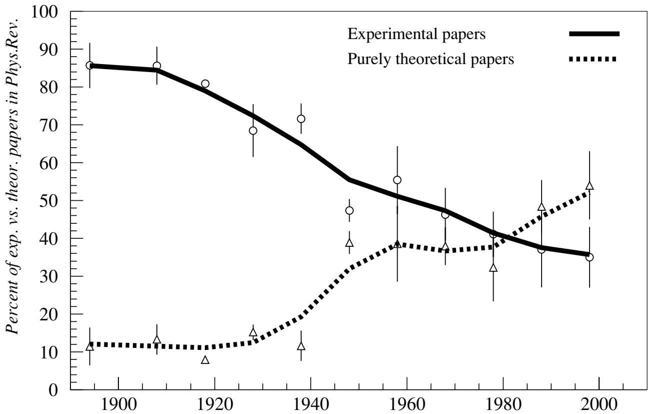

Fig. 1. Percentage of experimental/theoretical papers published in Physical Review. "Physical Review" is probably the most important physical journal. If the current trend continues, by 2050 experimental papers will represent only about 20%.

began in the 1920s and accelerated in the past 30 years[1)]. The methodology developed in this paper will make sense only if we try to put ourselves in the situation and turn of mind of earlier physicists who were living at a time[2)] when the main fields of physics had not yet emerged in a clear way. As an illustration, consider electrodynamics. In the late 18th century the great Italian physicist Alessandro Volta (1745–1827) was studying the effect of electrical shocks on the legs of frogs whereas at about the same time the American physicist Benjamin Franklin (1706–1790) with the help of a kite demonstrated that thunderclouds contain electricity. Although these phenomena have indeed a connection with the effects of electricity, nowadays they would no longer be included into a course on electrodynamics. The first effect would be ascribed to electro-physiology and the second to the field of atmospheric science. In the course of time, by

1) If the trend remains the same over the next decades, in 2050 we will have about 20% experimental papers and 80% theoretical papers, a situation almost completely reversed with respect to the one which prevailed in 1900. Moreover, it should be noted that this evolution is not specific to physics. An analysis of the papers published in the journal "Econometrica" shows that between 1933 (the date of its foundation) and 1980 the percentage of the articles which make some connection with statistical data decreased from 38% to about 10%. In addition many purely theoretical journals have been created: e.g., the "Journal of Mathematical Economics" and the "Journal of Economic Theory."

2) Broadly speaking about two centuries ago, but this figure is field-dependent. Mechanics was one of the first fields whose "core" was well identified and understood; for other fields such as electrodynamics this occurred somewhat later.

carrying out a great number of experiments of all kinds, physicists managed to separate and isolate the "core" of electrodynamics from its more accessory effects. The physicists of the twenty-first century may have forgotten some of the experimental skills of their predecessors, but this capability is still alive in the tradition of physics. We just need to revive it.

This paper tries to answer a simple question which I have been asked repeatedly by friends and colleagues: "Why should physics have something to say about social phenomena?" Whereas the purpose of biophysics or biochemistry appears clearly because physics and chemistry indeed provide experimental techniques which are very useful in molecular biology, the purpose of econophysics seems very unclear to most people. In this paper we argue that what physics can provide to social sciences is not a specific technique but rather the experimental methodology itself. Because, as mentioned above, physics has become a very formalized field, it is often thought that this methodology sums up to building a mathematical model which will then be tested by comparing its "predictions" to a set of data[3]. In fact, this is only one step (and probably the most formal one) in the experimental procedure. The other steps really provide new ways for exploring unknown phenomena. Prior to the modeling phase there is a process which aims at producing a set of data with the smallest possible level of noise. After the modeling phase the model must be used to predict some new effects which are substantially different from the one for which the model has been built and these predictions must then be compared with actual observations. We will come back to that important point in the concluding section.

In the first part of the paper we show how it is possible to identify the different mechanisms which are at work in falling bodies. In the second part, the same methodology will be used to identify essential mechanisms of social phenomena. As a case in point we will examine how suicide depends upon the strength of family bonds. In the conclusion, we discuss the role of models; finally we explain why in developing the observation-based approach that we advocate the Internet can be of great help.

2. Falling Bodies

As shown by the following excerpt from a book by John Von Neumann and Oskar

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[3] This in fact describes the methodology which is used in econometrics. First a model is constructed which contains a large set of parameters; then the model is compared to data which usually contain a high level of noise; finally, the parameters are adjusted by some statistical procedure (whose underlying mathematical assumptions are hardly ever questioned).

Morgenstern, the study of free fall has played an important role in the development of physics.

> *The free fall is a very trivial physical phenomenon but it was the study of this exceedingly simple fact and its comparison with astronomical material which brought forth mechanics. The sound procedure in every science is to obtain first high precision and mastery in a limited field and then to proceed to another somewhat wider one and so on".*
>
> (von Neumann and Morgenstern, 1944)

We now know that falling bodies are subject to two mechanisms: the attraction of gravity and the resistance of the fluid in which the fall occurs. Let us assume for a moment that we are not aware of the existence of these two mechanisms; how can we identify them?

Naturally, a first step is to observe how different bodies fall. We may, for instance, try the following ones:

- Steel ball of a diameter of 1 cm.
- Ping pong ball of a diameter of 4 cm.
- Light feather.
- Maple seed, i.e., a 3-cm-long brown wing of papery tissue which contains a seed at one end.

To the naked eye there is no visible difference in the motions of the steel and ping pong balls, which illustrates the well-known fact that in conditions where drag is negligible with respect to the gravitational force the law of motion is independent of the size, density and shape of the body. In contrast the motion of the feather is notably slower and for this very reason it is much more sensitive to perturbations such as draft or air turbulence. The motion of the maple seed displays a spinning movement when the initial configuration of the wing is horizontal; however the spinning movement does not start when the initial configuration is vertical. The last two cases illustrate the fact that when drag becomes important, there is no longer any universality; the law of motion depends upon the size, shape, density of the body, and even on its initial configuration with respect to the vertical.

The most striking fact in this experiment is the great variety of the motions: the fall of a feather has little to do with the fall of a steel ball, and the fall of the maple seed differs from all others in a spectacular way. Because the motion of the maple seed exhibits a

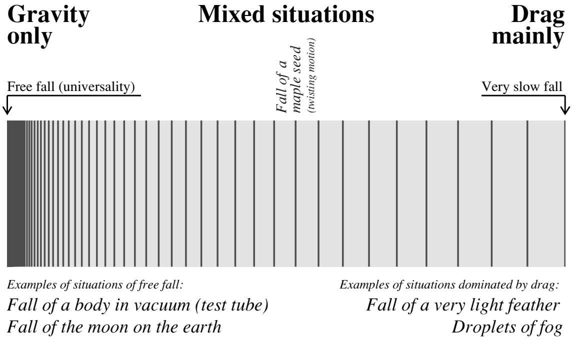

Fig. 2. Decomposing the motion of falling bodies into two simple mechanisms: gravitational attraction and drag.

The vertical lines schematically indicate the importance of the role played by gravitation. While the effects listed on the left-hand side involve only gravitation those on the right-hand side depend almost only on drag. Predominance of drag can be achieved in two ways: either by reducing the weight of bodies almost to zero or by introducing a force which opposes gravitation, for instance, the buoyancy created by the fluid in which the fall of the body takes place.

very distinctive spinning behavior it may be tempting to build a model which describes this behavior. However, if the two basic mechanisms have not been clearly identified such a model can be nothing else than a phenomenological model, by which we mean a model which is constructed not from first principles but with an eye on the kind of behavior one wants to describe. Such a model will have very little predictive power. It may describe the fall of the maple seed because it was built for that purpose, but it will be unable to describe the fall of steel balls or feathers. In short, it will allow very little understanding and progress.

If we wish to identify the two basic mechanisms we must consider situations in which one of them is predominant. This procedure is schematized in Fig. 2.

The main point is the fact that the laws corresponding to the two extreme situations are substantially simpler than mixed cases like the motion of the maple seed. Gravitational attraction is of course the simplest case overall. Very slow falls are described (at least for simple geometric shapes) by the law of Stokes. Incidentally, it may be noted that this domain of motion has a kind of weak universality in the sense that drag is then proportional to velocity for any Reynolds number as long as this number remains smaller than 1. In contrast, for Reynolds numbers larger than 1, drag is proportional to (velocity)$^\alpha$ where α depends upon the Reynolds number range. In short, we see that even a very simple case in which there are only two basic mechanisms can lead to fairly complicated and diversified effects.

We now come to the real challenge: how can we transpose this methodology to the social sciences? One of the main lessons that we learned from this example is that in order to isolate one effect we must look for *extreme situations* in which the factor that one wishes to study becomes predominant. We will now see how this approach can be implemented in the social sciences.

3. Effect of Marital Ties on Suicide

In order to illustrate how the previous approach can be applied we selected the phenomenon of suicide. There are several reasons for such a choice.

- Suicide has intrigued sociologists for a long time. One may recall that a key study by Emile Durkheim (1858–1917) which is considered one of the pioneers of sociology was his study of suicide.
- Suicide is challenging because it defies common-sense thinking. As an illustration one may mention the fact that the seasonal pattern of suicide is fairly counter-intuitive. For a country like France, common sense would expect that the suicide rate is highest in the months of November or December, which are marked by short days, cold and rainy weather, and bleak natural scenery. However, the evidence is completely different: it is in December that suicide rates are at their lowest and in May that they are highest[4)].
- As with most social phenomena, suicide is multi-faceted. Suicide rates are known to depend upon many personal characteristics: sex, age, religion, marital situation, place of residence (big city vs. countryside), and so on. Thus, suicide is a good case for showing how our previous procedure can be applied.

In this paper we focus on one specific factor, namely the marital state. The importance of this factor has already been emphasized by Durkheim. As a matter of fact, his thesis is that the more connections people have with their family, friends, or neighbors, the less

[4)] In addition, suicide is very little affected by political events. Thus, the attack of September 11, 2001, against the Twin Towers in Manhattan has had almost no influence on suicide rates: the rate for September is similar to the rates for August or November and the rates for September 11, 12 or 13 are similar to the rates for the other days of September. More details can be found in Roehner (2007, p. 205).

Table 1. Influence of marital ties on suicide rates.
Excerpted from chapter 9 of Roehner (2007)

	Time interval	Country	Males Ratio of suicide rates: unmarried/married	Females Ratio of suicide rates: unmarried/married
1	1889–1891	France	2.80±0.23	1.56±0.43
2	1881–1890	Switzerland	1.66±0.24	1.34±0.41
3	1911–1920	Norway	2.56±0.83	2.18±1.21
4	1968–1978	France	2.69±0.66	2.24±1.10
5	1970–1985	Norway		1.78±0.24
6	1981–1993	France	2.34±0.33	2.15±0.91
7	1982–1996	Britain	1.44±0.12	1.27±0.20
8	1990–1992	Queensland	2.67±1.20	2.11±1.60
9	1998–1998	Australia	2.21	2.00
		Average	2.30±0.24	1.85±0.32

There are two problems with these data:

- Does marriage act as a filter in selecting those people who are less inclined to suicide?
- The data show a substantial dispersion (>20%) in time and across countries.

Sources: 1: Durkheim (1897); 2: Halbwachs (1930); 3: Statistiske Centralbyrå (1926, Table 22); 4: Besnard (1997); 5: Høyer *et al.* (1993); 6: Besnard (1997); 7: Kelly and Bunting (1998, Fig. 4); 8: Cantor *et al.* (1995); 9: Steenkamp *et al.* (2000).

likely they are to commit suicide. Marital bonds are just one type of connection, yet probably the most important. Table 1 shows a set of comparative suicide rate data for unmarried versus married people.

At first sight the evidence presented in this table may appear quite compelling. However, there are two serious problems with these data.

- The first is an objection of a fundamental nature. Do these data really prove that the fact of being married reduces the likelihood of suicide? Not necessarily. Indeed, if we assume that the people who have a strong propensity for committing suicide cannot get married (for instance as the result of a physical or psychological deficiency) then the causality is reversed. It is not because people are not married that they commit suicide, rather it is because they have an inclination to suicide that they do not get married.
- The second problem is the substantial dispersion shown by these data. Consider for instance the ratios unmarried/married for men. If we accept the hypothesis that each line provides a result for a specific realization of a phenomenon which is basically the same

in all countries, then the accuracy of these measurements appears fairly poor. For France considered at different periods, the difference represents 18% but for France and Britain considered in almost the same time interval the difference represents 48%[5]. For physicists an error bar of 48% (or even one of 18%) would be considered very poor accuracy.

In order to respond to the first objection, a natural idea is to consider groups in which people cannot get married even if they wish to do so and even if in normal conditions they would be able to do so. Several groups of this kind can be considered. For instance monks or Roman Catholic priests cannot get married. But there are two difficulties. (i) It can be argued that the fact of becoming monks or priests reveals a special form of character which may involve an inclination to suicide. (ii) We were not able to find reliable data for the suicide rates of monks or priests. Groups of immigrants are much better candidates. When immigrant workers come to the United States, usually, the men come first and once they have been able to get a job and find a house they ask their wives and families to join them. As a consequence, the male/female sex ratio of immigrant groups is almost always higher than 1; in some specific historical situations it may be much larger than 1. In the mid-19th century many Chinese workers were recruited to build the Transpacific Railroad; as a result the sex ratio of Chinese immigrants reached a maximum value of $M/F=27$ in 1890. After that date it decreased steadily eventually reaching a quasi-equilibrium level of 1.02 in 1970.

Now, that we have found a situation which should provide a good observation point, there are of course two additional questions.

- Are there suicide rate data for Chinese immigrants and for American citizens of Chinese descent? The answer is yes. This is due to the fact that American statisticians have traditionally given much attention to the characteristics of ethnic subgroups in the American population. In a country like France, no statistics of that kind would be available. The American data were published annually in a series which, before World War II, was entitled "Mortality Statistics of the United States" and which subsequently broadened its scope and title to: "Vital Statistics of the United States."
- Once the sources for the data have been identified there is the problem of getting access to these publications. This could seem a fairly minor practical problem, yet before the advent of the Internet it was a very serious one. For instance, the collective catalog of French university libraries shows that the previous publications are only available at the

[5] For these percentages the denominator is the average of the two values.

National Library and even there some years (e.g. 1939–1944) are missing. Thus any broad statistical investigation would be very cumbersome. Now, thanks to the Internet, any of these volumes (each of them comprising about one thousand pages) can be downloaded within a few minutes.

Now that we have defined a suitable situation, that we have been able to find the relevant data, let us see what these data tell us. But before giving these results we would

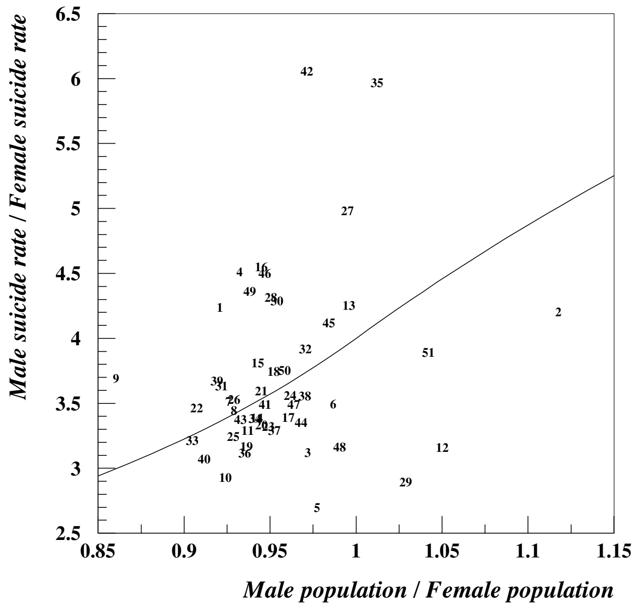

Fig. 3. A failed attempt to show the effect of marital bonds on suicide.

Horizontal scale: sex ratio *M*/*F*; vertical scale: *R*=Suicide rate of men/Suicide rate of women. Each of the data points corresponds to an American state (plus the District of Columbia). The suicide rates are averages over the five years 1979–1983. For *M*/*F* larger than 1, one would expect the suicide rate of men to increase with *M*/*F* whereas at the same time the suicide rate of women should remain constant, thus resulting in larger values of *R*. Similarly, for *M*/*F* smaller than 1, one would expect the suicide rate of women to increase as *M*/*F* becomes smaller, and thus *R* to become smaller. The expected behavior of *R* is represented by the solid line. However, the data points hardly follow any trend (the coefficient of correlation is 0.2 ± 0.3 which signals a non-significant correlation). This failure should be attributed to the fact that *M*/*F* is very close to 1; therefore the effect that we wish to observe is too weak compared to the impact of all other factors on suicide; these factors act as a source of background noise. In order to observe the effect of marriage on suicide more clearly this effect must first be amplified by selecting a situation where *M*/*F* is much larger than 1. This is done in Fig. 4. Source: *WONDER database* (available on the website of the Centers for Disease Control).

like to explain why a more standard approach (for the sake of brevity we call it the econometric approach) fails. One could make the following argument. "Why is it necessary to study such a special case as the Chinese immigrants? If one considers the 50 American states, they are characterized by sex ratios which all are different from 1. Thus, in a state where the *M*/*F* ratio is greater than one, some males cannot get married, hence one would expect a higher suicide rate for men. Even if the effect is small, one may think that there is nevertheless a good chance to get a meaningful result because one now has 51 cases instead of just one". Implementing the procedure suggested by this argument leads to the graph in Fig. 3.

As can be seen, this scatter plot shows no clear direction. Clearly the effect that we wish to observe is dominated by the noise; by this term we understand all local factors (apart from the sex ratio) which differ from state to state. Statistical tests, no matter how sophisticated they are, will be unable to extract any clear information from such a noisy dataset.

The results for the population of Chinese immigrants are presented in Fig. 4. The horizontal scale gives the *M*/*F* sex ratio. The point which corresponds to $M/F=6$ corresponds to the mid-1920s, the first date at which suicide rate statistics were available. At this time the sex ratio had already decreased from its peak value of 27 in 1890 to 6. The graph shows that, as expected, the suicide rates decrease as the sex ratio tends toward 1 that is to say as more and more men can get married[6]. The same observation can be made for Japanese immigrants. In this case, however, the sex ratio is much smaller, which means that a test restricted only to the Japanese group would not have been very significant.

How has the "theoretical" curve in Fig. 4 been obtained? It is based on three considerations (for the sake of simplicity we restrict the discussion to men; the same argument applies for women) (i) Our starting point is the ratio k_m of suicide rates for unmarried versus married males. In Table 1 this average ratio is 2.8; however, as none of the populations considered in this table are Chinese, some freedom in the adjustment of this parameter is required. It turns out that $k_m=4.2$ is more appropriate. (ii) The suicide rate of the males will be a weighted average of the rates of married and unmarried men. (iii) The suicide rate of married men $\bar{t}_m$ can be derived from the situation corresponding

[6] It is implicitly assumed that the Americans of Chinese descent only marry in their community; this was largely true at that time. Another assumption is that all males who can find a spouse due to the M-F composition of the population do indeed get married.

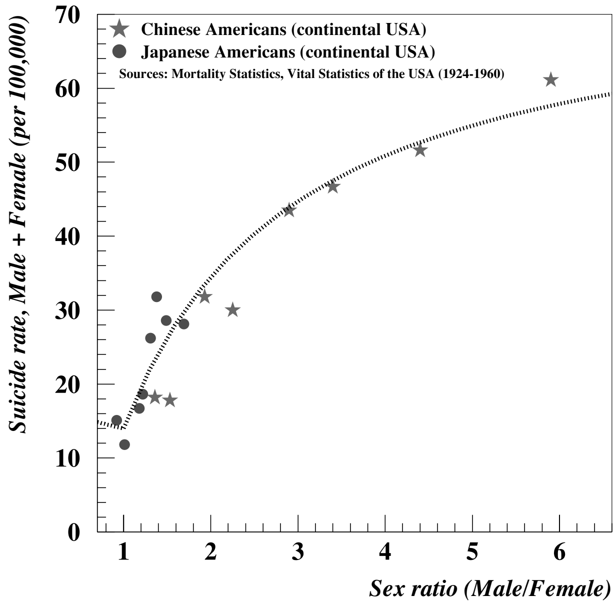

Fig. 4. Suicide rates in the Chinese and Japanese communities of the United States. The graph shows the (total) suicide rate of people of Chinese (stars) and Japanese (dots) descent established in the continental part of the United States. The star corresponding to a sex ratio of 6 is for the years 1923–1924. In subsequent years the sex ratio of the Chinese community decreased steadily until reaching a value around 1 in the 1960s. As the sex ratio decreased, more and more men were able to get married and one therefore expects their suicide rate to decrease. The curve represents this expected evolution. Sources: *Mortality Statistics of the United States* which subsequently became Vital Statistics of the United States, various years. All annual volumes are available online on the website of the National Center for Health Statistics.

to a sex ratio equal to one. In this way we get: $\bar{t}_{\rm m}=18$.

Another confirmation of the previous mechanism can be obtained from the suicide rates of women. In this case one does of course not expect any decrease because the women were always able to find husbands. Observation indeed shows that the suicide rate of women fluctuates around an average line without showing any trend (see Roehner, 2007, p. 185).

Two objections can be raised to which we wish to respond.

• A first objection would be to say: "The income of the Chinese and Japanese immigrants increased in the course of time, so it is not surprising that their suicide rate has been decreasing." It is of course true that the income and wealth of these immigrants has increased during the period of time considered in Fig. 4. However, it is *not* true that persons with a higher income are less likely to commit suicide; indeed, there seems to be a fairly clear relationship between suicide and income at least for the highest income brackets; this relation shows that the higher the income, the higher the suicide rate (Durkheim, 1897, II, Chapter V). Moreover, the evolution of the suicide rate of women also shows that the increase in income had very little impact on suicide rates.

- Another objection would be to say: "Is the decrease in suicide rates not common to the whole of American society?". The answer is no. For the United States the average suicide rate first increased from 1925 to 1935, then decreased until 1950, then remained fairly stationary. In other words, the evolution of the overall suicide rate is very different from what is observed in Fig. 4.

Although this case seems to be fairly convincing one cannot be content with just one case. One of the most important characteristics of physics is that once a new phenomenon has been discovered, the experiment is repeated (usually in slightly different forms) by other teams throughout the world. It is only once this process has been completed successfully that the new effect gets widespread acceptance. Similarly, it would be important to test suicide rates for immigrant groups in other countries than the United States to make sure that the effect is not specific to one country but has a broad validity. Of course episodes involving immigrants are fairly common. For instance the sex-ratio of Chinese immigrants in Australia in the 19th century was also very high, but so far we were not able to find suicide statistics for these immigrants. Nowadays, the immigrants from Pakistan and Bangladesh who work in Dubai are an overwhelmingly male population and would therefore provide a good test. Unfortunately, there are no suicide statistics for Dubai[7]. Even though we have not yet been able to find data for another case that does not mean that it is impossible. On the contrary, thanks to the Internet we are now in this respect in a much better position than ever before. The main obstacle which still remains is the language barrier. For instance, there may be useful data on Chinese or Japanese websites but if these websites do not contain English key-words I will not be able to find them unless I use Chinese or Japanese key-words.

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7) On its website the organization "Human Rights Watch" mentions that in 2004, the embassies of India, Pakistan and Bangladesh returned the bodies of 880 construction workers to their home countries. Yet the Dubai emirate, the only emirate to keep a count of migrant worker deaths, recorded only 34 construction deaths that year, based on reports from only six companies. If not even the deaths are reliably recorded it is difficult to trust any data about causes of death.

4. Models

Many papers published by econophysicists rely on modeling. That is why it is important to explain the role of models in the observation-based approach described in this paper. First of all one should realize that there is a great difference between modeling in physics and modeling in the social sciences. In physics there are many basic principles (e.g., conservation of energy, momentum, angular momentum, Newton's law of motion, the three principles of thermodynamics, the Heisenberg uncertainty principle, and so on) with which any model must be consistent. This puts great constraints on the construction of models. Therefore, if one is able to come up with a model which is consistent with the basic principles and which is also in agreement with the data, there is a good chance that this model really describes what happens. In sociology and in economics to the best of our knowledge there are no principles in the sense in which this word is used in physics that is to say rules which can be tested with a high accuracy. As a consequence, the situation of model building in the social sciences is completely different. Basically, any researcher can imagine a mechanism which he (or she) thinks represents what happens. For instance, for modeling stock markets there are (at least) four families of models based respectively on: (i) a minority game mechanism (ii) a distinction between so-called trend followers and fundamentals followers (iii) a pattern of log-periodic fluctuations in the vicinity of price peaks (iv) collective movement based on random matrix theory[8)]. With no constraints whatsoever on the construction of possible models, it seems clear that there can be as many models as researchers. This is basically the situation which prevails in sociology. Yet models certainly can be useful. Our observation-based perspective leads to the following requirements.

- Any parameter introduced in a model should have a clear operational interpretation in terms of observations. In this way, the parameters should, at least in principle (which means that it may occur that the required data are not available), be directly measurable instead of being adjusted.
- The model should suggest new observations. Once built, the model can predict the behavior of the system even in limiting cases (for instance when a parameter tends to the limiting values of its interval of variation) in which no observation has yet been carried out. As an example consider the model which gives the period of a simple pendulum: $T=2\pi\sqrt{l/g}$, where l is the length of the pendulum and g the acceleration of gravity.

[8)] More details on these models can be found in the Proceedings of the Prague Conference (Bouchaud *et al.*, 2001).

When, $l \to 0$ then $T \to 0$, which means that the oscillations of a very short pendulum become very rapid. To check this prediction will probably require the construction of a new pendulum especially designed for this purpose. It should have a very small mass otherwise the simple pendulum approximation will not be correct when l becomes very small; moreover, the articulation must have very little friction, otherwise the pendulum will stop almost immediately (when l is small the pendulum has very little potential energy even for a large initial angle). Once built, such a pendulum will provide an interesting verification of the model in a case which is different from the standard situation for which the model has been set up.

The same procedure can be used in the social sciences. Letting one parameter a go to a limiting value a_0 will produce a prediction for a situation different from the one for which the model has been set up. But, in the same way as we had to build a specially designed pendulum, now we have to find a real situation in which the parameter a really takes the value a_0. This may not be easy. However, if such a situation can be found it will provide a test of the model which is a *real test* in the sense that this behavior is different from the situation for which the model was built initially. If the prediction of the model is indeed in agreement with observation this will increase our confidence in the adequacy of the model.

5. The Key-role of the Internet Revolution

The implementation of the observation-based approach described in this paper crucially depends upon the availability of a broad collection of data corresponding to a variety of situations. In order to study the effect of a given factor or in order to test the prediction of a model, one has to pick the right situation. For instance, if we wish to study the effect of income on suicide rates we would need data for extreme cases that is to say for a population which has become very rich in the course of time. The population of a small oil-producing country where production has seen a rapid increase would provide a good testing ground. Before the advent of the Internet it would have been very difficult to find data for such a country, but now it is no longer impossible. That is why it is now the right moment to develop this approach[9].

[9] The reader may also wish to have a look at a related article (Roehner, 2008) which develops a similar argument but in a social science perspective; this may complement the present point of view especially for readers who are not physicists; it also contains many more references.

6. Complex versus Complicated Systems

Finally, we must answer a last objection. What makes us believe that this approach works? After all, social systems are often said to be "complex" and it is not obvious that an approach designed for physical systems may apply to them. In reply to this objection one can make two observations.

- The approach advocated in this paper has been successful not only in physics but also in meteorology. Atmospheric phenomena are certainly a case where it is difficult to separate one effect from another. Yet, this was achieved and gave us a fairly good understanding of most meteorological phenomena. The fact that the prediction horizon still does not exceed 8 or 10 days is due to the fact that the input data required to run the equations on huge computers are still not detailed enough and also probably to the chaotic character of some phenomena.
- We do not think that societies are complex systems in the same sense as a living cell or a brain are *complex systems*. Cells and brains are the results of an evolutionary process that covered four billion years. In contrast, societies are at most 1 million year old, and some important components of societies such as churches, states, or armies are actually much younger. It is probably more adequate to say that societies are *complicated* systems. What makes them complicated is the fact that they are highly heterogeneous systems composed of many different kinds of agents: priests, warriors, peasants, craftsmen, and so on and so forth[10]. The methodology delineated in this paper was put to work in a series of studies. The overall conclusion is that it was indeed possible to distinguish separate modules and mechanisms acting in more or less independent ways (see, for instance, Roehner, 2002).

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[10] The same observation applies also to stock markets. What makes stock markets complicated is the fact that there are many different kinds of companies and many sorts of agents from the small long-term investors, to day traders, to managers of huge investment funds; in addition, stock markets are open systems which are sensitive to many exogenous shocks whether economic, political, military, or social.

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References

Bouchaud, J.-P., M. Marsili, B. M. Roehner, F. Slanina (eds) (2001) Application of Physics to Economic Modelling. Proceedings of the NATO Advanced Research Workshop, Prague, 8–10 February 2001. *Physica A* 299: 1–2.

Durkheim, E. (1897) *Le suicide*. *Étude de sociologie*. Félix Alcan, Paris.

Roehner, B. M. (2002) *Pattern and Repertoire in History*. Harvard University Press, Cambridge, Massachusetts.

——— (2007) *Driving Forces in Physical, Biological, and Socio-economic Phenomena. A Network Science Investigation of Social Bonds and Interactions*. Cambridge University Press, Cambridge.

——— (2008) “Econophysics: Origin, Basic Principles and Perspectives,” in *Encyclopedia of Complexity and Systems Science*, Springer [to be published in 2008].

von Neumann, J. and O. Morgenstern (1944) *Theory of Games and Economic Behavior*. Princeton University Press, Princeton.