American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-6, Issue-2, pp-193-198
www.ajer.org
Research Paper Open Access

Considerations on Econophysics

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ABSTRACT: *This study highlights the relationships and analogies from the laws of physics with the strategic models defined from economic and financial applications. Scientists are interested in making analogies and speculations and then trace common patterns between fields as diverse as Physics and an Enterprise. In general, small businesses are constantly bargaining with its competitors in search of a reward to guarantee the right to continue competing among them. All the logic associated with this game is inspired by analogies with the processes of evolution of physics, which serve as an inspiration to achieve better results. Economics cannot escape this reality, and Econophysics is a new approach to produce significant results both in macroeconomics as in microeconomics. In general, experts agree that the fate of Econophysics shall be to clarify the future development of global markets.*

Keywords: *Physics, Enterprises, Science, Econophysics.*

PAC: *89.65.Gh*

I. INTRODUCTION

For Santos (2010), the challenge of entrepreneurs and strategists in nowadays business is similar to the physicists of the early twentieth century, that is, to manage your business with creativity in a chaotic picture and full of uncertainties. The business world has been looking for new ways in order to achieve increasingly promising results.

Economics is lively and constructive. It is not something ready and put in which it can be made use of. It grows and is built in a slowly daily process. For instance, the supply creates its own demand and, therefore, it leads us to an idea of perfect competition. However, the principle that supply creates its own demand stops working whenever there is a failure in confidence, which leads to a decrease in investments and a contraction in the business markets.

Facing a low consumption and crisis scenario, investment expectations are not good. Just as happened with the physicists, with the advent of modern physics for over one hundred years ago, entrepreneurs will face the challenge of building a different language to deal with the uncertainties of the chaotic modern world. Only then they may achieve positive results by creating an anticipation of the market which is in constant metamorphosis.

Scientists are interested in making analogies and speculations to trace common patterns between things as diverse as physics and businesses. In general, they are interested in systems and devices that to evolve and survive need to learn how to have a better interaction with their environment. In general, small businesses are constantly interacting and bargaining with their competitors in search of a reward that guarantees them the right to continue competing in the market. The most common behaviors, according to Fudenberg and Tirole (1984) are of the "puppy dog" (keeping small and without harming competitors), "top dog" (big and aggressive), "fat cat" (large and without aggression) and "lean and hungry" (small and aggressive).

All this logic is inspired by analogies with the evolutionary processes in Physics, which serve as an inspiration to achieve better results. This study seeks to emphasize the relationships and analogies of Physics with strategic models defined from Economics and Financial applications.

II. A BIT OF HISTORY

For Ribeiro (2010), Adam Smith was inspired by the Newton´s "Principia" to write in 1776 his classic "On the Wealth of Nations" in which he has used the idea of causal forces. In 1835, Adolphe Quetelet published a book entitled "A study in social physics" which sought to establish the laws of society similar to Newton´s laws. Alfred Marshall, in the beginning of the last century, used physical ideas of thermodynamic equilibrium to develop a new theory according to which an Economics system reaches the equilibrium state in an analogous manner to Maxwell and Boltzmann gases. In 1900, Louis Bachelier presented his doctorate thesis "Theory of Speculation", in which he used physical concepts such as the diffusion theory and applied ideas based on the Brownian motion to explain the formation of stock market prices (MANTEGNA and STANLEY, 2000).

According to Bassalo (2010), the first Economics models were strongly influenced by the Newtonian mechanism, with great support of differential and integral calculus, created by Newton himself. It can be said that the pioneers in this area were William Petty, who tried to shape Economics as a natural science regarding on Newtonian mechanics and François Quesnay, who sought the framework of Economics in a general and organic form.

William Petty wrote a book in which lies the genesis of the Monetary Theory and the Modern Economic Policy. Petty defines concepts such as value of labor power; monopoly; and fair wage. It has also discussed the concepts of amount of money and its velocity, which are based on the laws of motion and Newtonian balance.

Based on the postulates of physiocracy, François Quesnay drafted in 1758 an economic model for the French economy which was immortalized in the book “Tableau Économique”. It considered that the functioning of the economy corresponded to a natural order. According to this idea, the laws of nature govern human societies just as the discoveries of Newton govern the physical world (COSTA and FLÁVIO, 2005). All human activities, therefore, should be kept in harmony with these natural laws, especially the laws of Newton. The object of all scientific study was to find out the laws to which all phenomena were subjected to.

Quesnay (1993) sought to demonstrate, in that work, the relationship between the circular flow of production, circulation and distribution of wealth in an ideal and competitive free economy. For Quesnay, society was like a living organism, where the circulation of wealth and goods in the economy was like the circulation of blood in the body.

Another use of Physics in Economics appears in Adam Smith's work published in 1776. For Ribeiro (2010), Smith was inspired by Newton´s "Principia" to write, in 1776, his classic "On the Wealth of Nations" which used the ideas of causal forces. Adam Smith, who has lived in the time of the industrial revolution, noted that a new economic order was emerging in England, with steam as the driving force, and that would be it, the steam, the basis of industrial mechanization. The Newtonian balance of economic theory of Adam Smith was led by the "invisible hand" of the market, a guide of the personal interest of each entrepreneur, producer and consumer. In 1835, Adolphe Quetelet published the book entitled "A study in social physics" which sought to establish the laws of society similar to Newton.

For Ribeiro (2010), Quetelet has built his work based on a large accumulation of statistical data on several diverse categories of social phenomena, such as: economics situation, criminal evolution and also demographic aspects. He has believed that to build a social science, it was needed to make use of procedings and rules that were tested and applied to other sciences, that is, observe the social phenomena with maximum accuracy and then analyse the observational results within explanatory theories.

As pointed out by Belo (2004), Adolphe Quetelet, with his work “Research on the propensity for crime at different ages”, has taught that blood crimes happen more often in the summer and the ones against property in the winter. He has also claimed that the society generated the crime and the criminal would be only his executor. For the author, the crime would be a phenomenon of masses and not of the individual, and the statistical method was the most suitable for its proper research.

In 1691 John Locke published "Some Considerations on the consequences of the Lowering of Interest and the Raising of the Value of Money" in which he formulates the quantitative theory of money, attaching great importance to the money velocity to the impact of the price of a product.

According to Silva (1987), Locke studies the quantitative equation providing great importance to the money velocity. It is the main advocate of the idea that economics should be addressed by the free play of supply and demand to constitute the price formation.

III. CONSIDERATIONS ON POWER LAWS

In 1897, the engineer and Italian economist Vilfredo Federico Damaso Pareto presented his famous power law, from which the probability, p(x), of the occurrence of an event of magnitude x is given by x-α. The input α is a scale parameter which can be determined by empirical observation of a system or through simulation.

Currently, more and more power laws are discovered by econophysicists in financial markets. It can be exemplified by the São Paulo stock market, its volatility and the foreign exchange rates. Pareto's law is a typical power law and it has become the rule of thumb in business: 80% of sales come from 20% of customers.

An extension of the Pareto law are the "Levy's flights" and the "Truncated Levy's flights". They seek to more accurately predict the occurrence of rare events (MANTEGNA and STANLEY, 2000). These types of probability distribution are commonly called "fat tailed", given the non-zero probability of extremely rare events (VISWANATHAN, 2003). To understand the origin of these distributions in complex systems is a classic problem in physics. Being able to predict the next rare event means to get to know in advance when the next crisis might occur and thus, mitigate risk and maximize profits.

IV. CONSIDERATIONS ON BROWNIAN MOTION

The field of statistical mechanics was developed in the last century. It is related to random movements and motivated especially by Brownian motion. In the 1970s, there was the creation of a new matter relating economics to physics: it has been called by the term Econophysics.

It can be said that the Brownian motion was discovered by Robert Brown in 1828. It was observed experimentally with the aid of a microscope, in a suspension of pollen grains in water. Each grain was moving erratically, stirring constantly, as if they had life. As this phenomenon was repeated with all kinds of organic substances, Brown believed he had found the primitive molecule of living matter. Later it was found that also dust grains, of mineral origin, had the same strange behavior. No one seemed to understand the origin of this cluttered and continuous movement, the "Brownian motion".

In 1905, one of the four revolutionary works of Einstein solved the Brownian motion phenomenon. According to Einstein, the perpetual motion agitation of dust particles suspended in a liquid has to do with the thermal motion of atoms constituting the solution in which the particles are.

Adduces the basic laws of mechanics, the distance traveled by a mobile is proportional to the time, at a given speed. According to Einstein, in the case of Brownian motion, the concept of speed no longer makes sense, because the distance traveled is no longer proportional to the time, but to its square root. The atom could not being seen through the microscope, but the action of their multiple collisions with a grain of pollen could be. In each instance, the number of atoms colliding with the grain is slightly higher in a given direction, and pushes it in that direction. The next moment, the numerous atoms around the grain push it to the other side. So the grain seems to have an inordinate movement, as a drunken person walking down the street. The particles move as a rapid irregular dance, continuously changing direction due to collisions with other particles in the solution.

Einstein's work on Brownian motion had an enormous influence on scienc e, since the diffusive model of Brownian motion continues to be a source of inspiration for physicists, biologists, economists and mathematicians. Issues as diverse as the movement of automobile traffic, the evolution of the stock market or the diffusion of nutrients across cell membranes are studied using mathematical models inspired by the theory of Brownian motion.

A new relationship between physics and economics was presented in 1900 by the French mathematician Louis Bachelier who defended at the Academy of Sciences in Paris, his thesis entitled "Theorie de la Speculation". This thesis dealt with price options on speculative financial markets based on the Brownian motion (MB), received a bad concept of its examiners and therefore was rejected.

After being forgotten for a long time, the idea of Bachelier on MB of financial markets was resumed in 1965 by Samuelsen, and early years of the 1970s, by the American economists Fischer Black and Myron Samuel Scholes, but this time with much more success. They have earned the Economics Nobel prize for the researchers (MACIEL, 2007).

They have developed the famous Black-Scholes model price option, in which the price follows a geometric Brownian motion. The process, governed by MB, takes place in the financial market and refers, roughly, to the sum of the contracts made between buyers and sellers of a product or service and the intermediation of the interaction between buyers and sellers that determines prices and production factors.

V. VOLATILITY FORECAST – AUTOREGRESSIVE PROCESSES

One example of the many possible applications of Econophysics is in modeling and forecasting the volatility of the change of the stock price. This topic is of great interest since it allows to identify with greater accuracy the risk exposure of a portfolio for example, and it is used as an input for purchase or sale of assets by investors.

Volatility is a measure of market fluctuations in a given time interval and is related to the amount of information that the market receives. A definition of price volatility P(t) in a time window T can be given by:

$$\sigma_t = \frac{\sum_{t=1}^{T} \sqrt{\langle P^2(t)\rangle - \langle P(t)\rangle^2}}{T} \qquad (1)$$

The volatility follows a power law of the form $\sigma_T \approx T^{\mu}$, where the Brownian motion is a specific case for the value of $\mu = 0.5$.

To model the volatility of price change, it is used a process called GARCH(p,q) to forecast its variance, defined by Bollerslev (1986), as an extension of the linear autoregressive processes:

$$\sigma_t^2 = \alpha_0 + \alpha_1 x_{t-1}^2 + \ldots + \alpha_q x_{t-q}^2 + \beta_1 \sigma_{t-1}^2 + \ldots + \beta_p \sigma_{t-p}^2 \qquad (2)$$

Where the Greek letters alpha and beta are the control parameters, non-null positive values, and the terms x is a random variable of mean zero and variance σ is obtained from a previously chosen conditional probability. Usually, the initial model choice is a GARCH(1,1) with a Gaussian distribution of the random variable as:

$$\sigma_t^2 = \alpha_0 + \alpha_1 x_{t-1}^2 + \beta_1 \sigma_{t-1}^2 \qquad (3)$$

The opportunities for econophysicists contribution in this topic are mainly to discover the distribution that best fits the data, since the actual distributions of price changes rarely are Gaussian (Onody, RN et. Al., 2007), and in how the parameters are calculated (POKHILCHUK, KA and SAVEL'EV, SE, 2016).

It is worth mentioning that this area has a large intersection with another area of economics called Econometrics and there are several studies comparing the two approaches to this problem (Koh, J. S. H. (2008)). Knowing how to extract the best out of both approaches might bring the best results for businesses.

VI. DISSIPATIVE PHENOMENA

The analysis of the economic phenomenon had a new breakthrough when Nicholas Georgescu Roegen, in his book "The Law of Entropy and the Economic Process," published in 1979, noted that the economic theories developed until then, relied on primitive mechanism of Newton laws, which despised the internal and external mechanisms of dissipation as a result of friction.

In any state of aggregation molecules are animated with chaotic motion, or thermal agitation; this provides thermal energy to the system that is not heat but is part of the internal energy U of the system, with great tendency to be dissipative. In regard to unique kinds of mechanical energy, there may also be conservation between them. For example, all the gravitational potential energy can be transformed completely into kinetic energy, without any creation of any other non-mechanical type of energy.

Energy conservation occurs only in the absence of dissipative forces like frictional force and air resistance force, because otherwise, as the energy is transformed into several types, there is a certain amount that degrades. The unit that measures this degradation is called entropy. The lower the entropy of a form of energy, the smaller the degradation and thus it can be processed more efficiently in other types of energy.

Entropy can also be understood as a measure of the disorder of a particular form of energy in a system. Thus, the lower the entropy of a particular form of energy the more "ordered" it is within a given system.

As explained by Cechin and Veiga (2010), Georgescu Roegen decided to introduce the dissipation of energy in production processes by studying the entropy and the steam engine, he had noted that the dissipation of energy was important both for the said machine performance. Then he had resolved to make a correlation to Economics. The production processes of modern industrial society cause great social friction and, consequently, there is dissipation of resources the economy, as part of such resources should be used in unproductive activities. So for Georgescu Roegen, the Newtonian balance that characterized the Economic Models from Petty should be replaced by thermodynamic efficiency, i. e., such models should seek to reduce the entropy caused by social tensions caused by the production process.

In 1977, the Russian Ilya Prigogine won the Nobel Prize in chemistry due to his research on the theory of dissipative structures, which gives ample highlight to the uncertainties from a possible chaotic state. Among other things, Prigogine states that "there are no more stable or permanent situations that we are interested, but developments, crises and instability".

The central idea of the theory is that small changes in initial conditions of a system can cause drastic changes in this system future. It might be the climate of a region, the movement of the stock exchange or in inflationary explosion, the eruption of a volcano or an earthquake.

In addition, Prigogine shows several examples in which random fluctuations can give rise to more complex forms and then a sudden reorganization arises to a more complex shape.

VII. ORDER AND DISORDER

For instance, it can be said that, in general, matter has the tendency to become more ordered to the extent that it is cooled. However, some systems appear to be more disordered as the temperature drops down. After all, what is the correct meaning of order and disorder?

The process involved in the simple act of frying an egg can help us to understand the laws that govern nature. According to Marcelo Gleiser, a simple example to understand entropy is to cook an omelet. Never shall you see the omelet turning back into an egg. This process shows that there is a preferred direction for the passage of time and it is characterized by a start in an organized state which tends to end in a disorganized state.

The amount of disorder of a system is represented by its entropy: the more organized the system is, the lower its entropy is. The egg in the example above has lower entropy than the cooked omelet. This increase in entropy is another expression of the second law of thermodynamics: in an isolated system (no energy exchange with the outside), the entropy never decreases and can only grow or remain constant. And as the second law is also related to the direction of the passage of time, we can say that time goes forward because the entropy grows. An egg breaks when it falls off the table on the kitchen floor, but the broken egg does not climb back to the table and returns to its original shape.

Let us look at another interesting example. To boil an egg, the heat absorbed causes a temperature increase and increases the entropy, but hardens the egg, which seems to correspond to a more orderly state. However, the situation involving a cold egg and a boiled egg is different, because by warming the egg, it seems, features a system out of balance, due the presence of the heat received during the process.

Consequently, a mechanistic analysis of economic phenomena does not allow a clear distinction between the past from the future operations, and, what is more important, does not include the irreversible processes. The physical property that allows a differentiation between a thing of the past in relation to another of the future and also to consider the irreversibilities of the systems is the Entropy (PRIGOGINE, 1997). In terms of irreversibilities, we have to consider them from the internal and external point of view of the system.

That said, it is considered that economic processes are further specified with the introduction of laws and principles of thermodynamics of open systems, which includes the concepts of order and disorder, and even topics of the Darwin´s theory of evolution.

According to the theory of evolution, life on Earth began with fairly simple unicellular and, over time, became increasingly complex, increasingly organized. How was it possible that highly organized forms to flourish amid the increase of entropy? A question, by comparison, could be placed. This is to explain how economic models could, or not, reach a state of equilibrium, with disorder and maximum entropy.

However, it would be illusory to try to frame the modern economy as an exact science, hoping that their behavior is identical to those associated with thermodynamic systems. Between metaphor and reality there is an abyss of differences. It is necessary to keep in mind that there are some factors involved in the Economics and the Finances that are not simply mathematical notions, but are inherently psychological notions of the individual, such as the concepts of risk and value. The optimum point between the concepts and applications of econophysics with the concepts and economic theories is precisely in this quest to find the equilibrium and the relevance of each of these concepts to the problem in question.

VIII. CLOSING REMARKS

What are the issues that can be questioned on the connection between physics and finance? What are the scales that must be considered to find a parallel between these two sciences? The set of mathematical methods and concepts developed to study these structures is called Complex System Physics.

The physics involved in these investigations has began to draw interest and to be studied just recently, restricted to only a few first studies on biology systems, or on economic information.

Therefore, works on ecosystems, neural networks or financial markets have begun to conquer more and more space in most of the influential magazines of physics.

On the other hand, the word Econophysics is relatively new. It is a concept that emerged around 1998, after the banks plus the major US financial centers have started to hire theoretical physicists to work with financial products such as bonds and stocks. There is a tendency, very young, to implement the physics curriculum with the area of complex systems, which includes, among other things, notions of dynamic systems, stochastic systems, time series analysis, the fractal theory, game theory, control theory, graph theory, decision and information theories.

It has been realized by economists and physicists that, increasingly, physical or biological models can simulate and help understand the dynamics of the economic and financial environment.

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