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# STOCK MARKET - THE ECONOPHYSICS APPROACH

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***Abstracts:*** *In the past decade or so, physicists have begun to do academic research in economics. Perhaps people are now actively involved in an emerging field often called Econophysics. Econophysics applies statistical physics methods to economical, financial, and social problems. In this work, we attempt to introduce an Econophysics approach to general stock index of stock market. The main goal of this study is fourfold: (1) First we begin our approach through the relation between the stock price and thermodynamics by using of simple volatility model. (2) Next here we introduce the Newton´s law of cooling by using of energy transformation in the economic system. (3) Then we extend the economic energy transformation in the stock markets. (4) Finally, we construct the stock markets related to the thermodynamics with using of newton's law of cooling. And this paper end with conclusion.*

***Keywords:*** Thermodynamics, Econophysics, Newton´s law of cooling, Stock market.

## INTRODUCTION

Econophysics, which is nowadays a broad interdisciplinary area, but rather as a pedagogical introduction to the mathematics (and physics?) of financial derivatives.

Econophysics concerns the use of concepts from statistical physics in the description of financial systems. Specifically, the scaling concepts used in probability theory, in critical phenomena, and in fully developed turbulent fluids. These concepts are then applied to financial time series to gain new insights into the behavior of financial markets. It is also present a new stochastic model that displays several of the statistical properties observed in empirical data.

Usually in the study of economic systems it is possible to investigate the system at different scales. But it is often impossible to write down the 'microscopic' equation for all the economic entities interacting within a given system. Statistical physics concepts such as stochastic dynamics, short- and long-range correlations, self-similarity and scaling permit an understanding of the global behavior of economic systems without first having to work out a detailed microscopic description of the same system. Econophysics will be of interest both to physicists

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and to economists. Physicists will find the application of statistical physics concepts to economic systems interesting and challenging, as economic systems are among the most intriguing and fascinating complex systems that might be investigated. Economists and workers in the financial world will find useful the presentation of empirical analysis methods and well formulated theoretical tools that might help describe systems composed of a huge number of interacting subsystems.

No claim of originality is made here regarding the contents of the present notes. Indeed, the basic theory of financial derivatives can now be found in numerous textbooks, written at a different mathematical levels and aiming at specific (or mixed) audiences, such as economists [1, 2, 3, 4], applied mathematicians [5, 6, 7, 8], physicists [9, 10, 11], etc.

The aim of this paper is to introduce an econophysics approach to the general stock index of stock market.

## STOCK PRICE AND THERMODYNAMICS [12 - 19]

For the financial markets analysis, the proper instruments of technical analysis that can provide valuable information about the evolution of the various transacted assets are used. Among the instruments of technical analysis, those used the most by investors are simple graphs to indicate the prices evolution or the volumes transacted, the simple volatility or logarithmically expressed volatility, simple averages or Bollinger bands and lesser other indexes, stochastic oscillators etc., which are approached by the specialists or financial analysts.

For volatility, the relation that gives the shares price difference at two successive moments is usually used:

$$Vol = p_t - p_{t-1} \tag{1}$$

Where $t$ represents the present time, and $t$–1 is the at the previous moment, separate from $t$ by the time unity (minute, hour, day, month year etc.), as well as logarithmic expression.

$$Vol = ln(p_t) - ln(p_{t-1}) \tag{2}$$

Which allows the graphic representation for longer time periods.

From the stock-markets analysis it is sometimes established that, although some assets with high prices are well appreciated, having an increasing tendency of the price, they are characterized by a diminished liquidity because of smaller transaction volumes, leading to ampler price oscillations, i.e. more risky for investors. Contrarily, the assets with a more reduced price that can attract the investors, consequently being able to determine large transacted volumes, can inspire some confidence on the market although the shares do not have a corresponding good evolution (having many price oscillations and price corrections etc.).

In the first case mentioned it can be said that such a share of high value, has a much more inertia on an increasing/decreasing tendency of the transacted price and at the same time, by reduced liquidity, is much more risky, as will compare a lump pile with a sand hillock. Even if the volume should be the same, the effects are very different.

From this point of view the product price is multiplied with transacted volume can be assimilated with to impulse of a particle defined by the product of mass $m$ and speed $\upsilon$:

$$p = m \cdot \upsilon \tag{3}$$

For a more complete understanding of the share evolution from the point of view of the price and transacted volumes, the product price multiply with transacted volume can be assimilated to the impulse of a particle (which symbolize the respective financial information) defined by the product $pV$ similar to the impulse of a particle-information defined by a relation of (3) type.

Such an index can delivers ampler useful information regarding the "inertia" degree or stability of an asset (shares, financial instruments etc.) than the price, $p$, or the transacted volume, $V$, taken separately.

In the like manner, it can be also considered other parameters that result from combinations of the two entities of the type: price/volume or volume/price etc., all these combinations can be symbolically marked by parameter $a_1$.

Considering the product price multiply with volume, $a = pV$, we can defined the normalized volatility as:

$$Vol_n = \frac{p_t V_t - p_{t-1} V_{t-1}}{p_{t-1} V_{t-1}} \tag{4}$$

Where

$p_t$ is the closing price from the day $t$;

$V_t$ is the number (volume) of transacted shares in the day $t$;

$V_{t-1}$ is the number (volume) of transaction shares in the day $t-1$;

$p_{t-1}$ is the closing price from the previous day $t-1$.

The normalized volatility represents a powerful index of the share's state (condition or status etc.) compared with the previous day and meanwhile an information referring to the investor perceiving with respect to the asset and theirs expectations toward the investment in the respective share (company) from a moment to another.

**NEWTON'S LAW OF COOLING [20 ]**

Temperature difference in any situation results from energy flow into a system or energy flow from a system to surroundings. The former leads to heating whereas latter leads to cooling of an object.

Newton's law of cooling states that the rate of temperature of the body is proportional to the difference between the temperature of the body and that of the surrounding medium. This statement leads to the classic equation of exponential decline over time which can be applied to many phenomena in science and engineering, including the discharge of a capacitor and the decay in radioactivity. Newton's Law of Cooling is useful for studying water heating because it can tell us how fast the hot water in pipes cools off, and also tells us how fast a water heater cools down if you turn off the breaker when you go on vacation.

Detailed aspects of the model under consideration appear in [21]. Because this model is based on the physic's formalism of Thermodynamics, basic thermodynamic quantities must be defined at first.

$N$ = The number of stocks being traded.

$E$ = Define energy as the prize which an investor wants to buy or sell a stock. For an index, $E$ is a weighted mean average of the stocks which all investors want to buy or sell.

$T$ = Defines Temperature as the mean average of one stock's prize or stock's index at a given time step where transactions are taking place. This is a reasonable conclusion derived from the definition of Temperature as the mean value of energy

$$T = \overline{E} \tag{5}$$

It must be stressed that the notion of transactions in the terminology of statistical Physics means "interactions". In this model it is assumed that the mean average of one stock's prize follows a law or a path of exponential nature, due to interactions of the constructed system with external heat reservoirs. Thinking of a reservoir it is considered as a set of income and information, which potentially are able to cause an uptrend or downtrend. A definition of the heat capacity is given below:

If the entire body is treated as lumped capacitance heat reservoir, with total heat content which is proportional to simple total heat capacity $C$, and $T$, the temperature of the body, or

$$Q = CT \tag{6}$$

It is expected that the system will experience exponential decay with time in the temperature of a body.

From the definition of heat capacity $C$ comes the relation $C = dQ/dT$ (7)

Differentiating this equation with regard to time gives the identity (valid so long as temperature in the objects is uniform at any given time).

$$\frac{dQ}{dt} = C\left(\frac{dT}{dt}\right) \tag{8}$$

This expression may be used to replace $dQ/dt$ in the above equation (6). Then, if $T(t)$ is the temperature of such a body at time $t$, and $T_{env}$ is the temperature of the environment around the body.

$$\frac{dT(t)}{dt} = -r\left(T(t) - T_{env}\right) = -r\Delta T(t) \tag{9}$$

Where

$r = hA/C$ is a positive constant characteristic of the system, which must be in units of $s^{-1}$, and is therefore sometimes expressed in terms of a characteristic time constant $t_0$ given by

$$r = \frac{1}{t_0} = \frac{\Delta T}{\left(dT(t)/dt\right)} \tag{10}$$

Thus, in thermal system,

$$t_0 = \frac{C}{hA} \tag{11}$$

The total heat capacity $C$ of a system may be further represented by its mass specific heat capacity $c_p$ multiplied by its mass $m$, so that the time constant $t_0$ is also given by $mc_p/hA$.

The solution of this differential equation, by standard methods of integration and substitution of boundary condition, gives

$$T(t) = T_{env} + \left(T(0) - T_{env}\right)e^{-rt} \tag{13}$$

If $\Delta T(t)$ is defined as $T(t) - T_{env}$. Where $\Delta T(0)$ the initial temperature difference is at time 0, then the Newtonian solution is written as:

$$\Delta T(t) = \Delta T(0) e^{-rt} = \Delta T(0) e^{-t/t_0} \tag{14}$$

It is supposed that the stock exchange itself is a body with a heat capacity. The law, by which the mean average of a stock prize/index is changing, is given by Newton's law of cooling. This relevant law is expressed by equation following equation.

$$\frac{dT(t)}{dt} = -r(T - T_{env}) \tag{15}$$

The solution for equation (15) is given by the relation below

$$T(t) = T_{env} + (T(0) - T_{env}) e^{\pm rt} \tag{16}$$

In above equation (16), $T_{env}$ reflects an important constituent of the constructed model. $T_{env}$ is the temperature of the reservoir that contacts a certain stock market associated with a certain stock index represented by $T$ and causes uptrend (heat) or downtrend (cooling).

The constructed model bears a notion of the drift coefficient (μ), but in a conceptual way rather than analytically. This means that this coefficient is not given by an analytical equation, but within the very internal foundations of our formalism. Hence it is supposed that the drift parameter changes because systems with different temperatures are coming in contact with each other and, in the case of this study, these systems are considered as heat reservoirs. The stock exchange itself is a heat body and the study concentrates on the changes in its structure. Other heat reservoirs (new potential income gains, new players which buy and sell their portfolios, stock market merge et cetera) are coming in contact with this system, thus causing changes in its structure. Every system has some certain characteristics like temperature, capacity. The temperature difference each system has from the system under consideration, may potentially cause, a heat (income) flow, when it comes in contact with the constructed system.

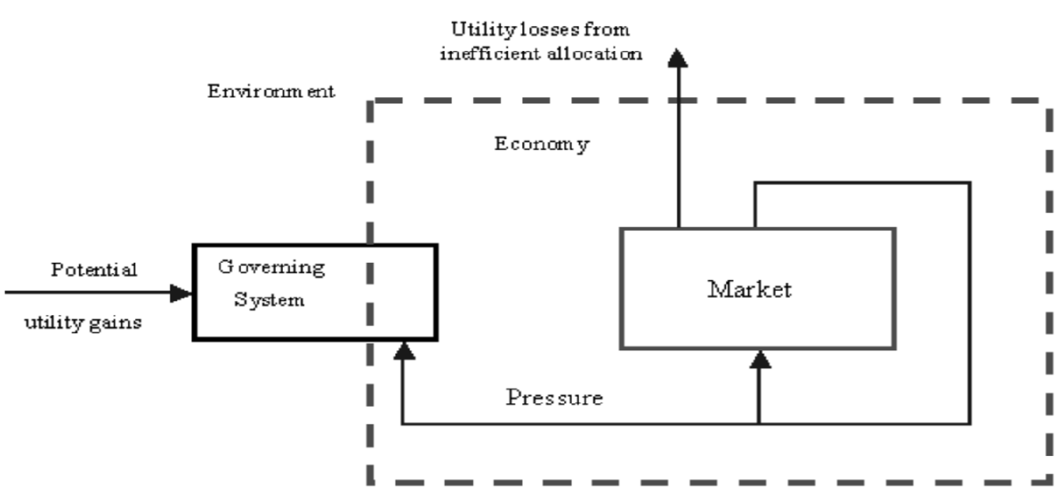
Hence, the drift coefficient (μ) is revealed by the change of temperature in the constructed system, when other heat reservoirs are coming in contact with, and the question whereas the temperature will rise or fall (exponentially) and how much, depends always on the temperature of these reservorios.

## CONSTRUCTION OF HYBRID MODEL

Significant empirical evidence now subsists of the stock returns deviating from the lognormal distribution with "fat tails" and a "sharp peak" which better fit the truncated Levy flights or other power law distributions [22, 23, 24]. In this context, several studies on stock market data have shown the existence of nonlinear characteristics and chaotic behavior that lend credence to the existence of a statistical feedback mechanism of market players. Explanations for the existence of "fat tails" in stock market data have been offered on this statistical feedback process e.g. "extremely events" cause "disproportionate reactions" among market players. This deformed noise may also capture the "herd behavior" of stock market investors.

From the thermodynamics point of view [25-27], systems of economy behave in a manner shown in figure 1. The stock market is an open system, which shares are issued and traded either through exchanges or over-the-counter markets. This is similarity of open thermodynamics system in which the matter may flow in and out of the system boundaries. The first law of thermodynamics for open systems states that the increase in the internal energy of a system is equal to the amount of energy added to the system by matter flowing in and by heating, minus the amount lost by matter flowing out and in the form of work done by the system. In financial markets particles are the stocks and all the other exotic assets that we can trade in different kind of markets. The price of the stock also corresponds or better, is related to the chemical potential of the system. In thermodynamics, the chemical potential of the system, an expression of the system's state. A quantity that determines the transport of matter from one phase to another, a component will flow from one phase to another when the chemical potential of the component is greater in the first phase than in the second. This state in thermodynamics depends on the

**Figure 1: Energy Transformation in the Economic System**



environment, which is described with macroscopic entities like temperature T or pressure P. When the system is placed in a hotter environment of bigger temperature, in other words, when it is in touch with a hotter reservoir, its temperature rises up according to the Newton's law and when it is placed in a lower temperature environment, i.e.

Newton's Law of Cooling describes the cooling of a warmer object to the cooler temperature of the environment. Specifically we write this law as,

$$T(t) = T_e + (T_0 - T_e)e^{-kt} \tag{17}$$

where $T(t)$ is the temperature of the object at time $t$, $T_e$ is the constant temperature of the environment, $T_0$ is the initial temperature of the object, and $k$ is a constant that depends on the material properties of the object. We are expecting to observe similar changes in the chemical potential which of course for the markets is corresponding to their prices. According to Newton's law, temperature $T$ depends on time. This dependency is expressed with the following form

$$T - T_{res} = (T_0 - T_{res})e^{-\lambda(t-t_0)} \tag{18}$$

## THE COLLECTIVE BEHAVIOUR AT STOCK MARKET

Now we have to consider a very important question directly related with the study of stock market related to the thermodynamics with using of newton's law of cooling. From the above discussion, it seems quite enough to make us propose a law between the price of the indices and time of the form

$$P - P_{target} = (P_0 - P_{target})e^{-t} \tag{19}$$

This above equation is similar to the Newton's law of cooling in physics. The Newton's law is the formula that describes the way a system is absorbing energy in a macroscopic way, using the magnitude of temperature. Suppose that the temperature of the system is $T_0$ at time $t_0$. When it gets in contact with an environment, which has higher temperature $T_{res}$, the heating process begins, and temperature rises up following an exponential law of the form Equation (18). At $t_1$ time units after the contact with a hotter reservoir, the system is at a new temperature $T_1$. If at that point in time, we bring the system in an environment, which has some lower temperature, a freezing process will begin which follows the same exponential law. That is why, at time $t_2$, the system will fall to a new temperature $T_2 < T_1$ since it is now heading to a state of thermal equilibrium with its environment of temperature $T_0$.

In correspondence with the above, we recommend that, the stock markets, as were placed in an economic environment of temperature $T_{res}$, and experienced an exponential "heating process" until $T_1$. That followed in both cases by a "freezing process", which pushed the prices at a level close to that of the starting "economic environment temperature" $T_0$. In both cases, there is a slight difference between the starting environment temperature $T_0$ and the final temperature $T_{res}$, something that under this point of view indicates the real amount of economic growth, in thermodynamic terms, in this time period.

The fact that there is a big difference between the real economic growths

$$T_{res} = T_2 - T_0 \tag{20}$$

And the observed "expected" economic growth

$$\Delta T_{\text{expected}} = T_{res} - T_0 \tag{21}$$

in these stock markets, is a consequence of the herding behaviour that took place in both cases from the micro investors that were the majority of the players both in absolute numbers and in capital terms. So, we can assume that "Newton's law kind of patterns" is the result of such collective responses of the investors. No rational fundamental analysis or chartist strategy can easily create such patterns in the stock markets.

## CONCLUSION

From the above, we discussed the scope of the phenomenological analysis for stock market through the econophysics approach especially the Newton's law of cooling in thermodynamics. Here we discussed our approach through the relation between the stock price and thermodynamics by using of simple volatility model. Then we introduced the Newton´s law of cooling by using of energy transformation in the economic system. And it followed by then we extended our economic energy transformation in the stock markets. Finally, we constructed the stock markets related to the thermodynamics with using of newton's law of cooling.

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