ECONOPHYSICAL GRAVITATIONAL MECHANICAL MODEL OF MICROECONOMICAL SYSTEMS OF STOCKS

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Abstract. *As physics is the science that describes quantitatively the processes of nature with the application of knowledge of mathematics with approximated models, also econophysics can applies the different physical models in order to describe quantitatively different processes in economics and in such way the estimation about the state of economical processes can be given as at the given moment as well as in the future.*

As the microeconomics that describes how the customers decide about the buying of goods and how the change of prices and their incomes influence on their decision about the purchasing, so econophysics can use such physical model to explain theses decisions about purchasing under the influences of changing of prices and the incomes of customers.

An important parameter for the microeconomial system is the stock reserve (inventory) measured in amounts of packing products or in national currency and how it behaves in time. This behavior in time of the inventory of microeconomical system is not nothing but like a movement of "material body" in the field of dissipative and conservative forces. The field of conservative forces can be the analogy of gravitational field with the important parameter gravitational acceleration.

An important physical law is the law of conservation of energy, and the case when dissipative forces are absented then the potential energy that is related to the inventory is totally transformed into the revenues (kineticcal energy). The term of kinetical energy is related to the revenues but the potential energy is related to the stock reserve (inventory). The friction forces that are the kind of dissipative forces are neglected meaning that other types of payments are absent, or other types of payments related to salaries, services, rents etc. are neglected or absent in comparison with the revenues. The initial value of stock reserve can be restored when a part of revenues are used to pay to the distributors (dealers) in order to restore the initial value of the stock reserve. So, the fields of conservative potential forces are related to the payments to the dealers, but the payments related to salaries, services, rents etc. are referred to the fields of dissipative non-conservative forces. Assets of the firms (or microeconomical systems) are referred to the fields of conservative potential forces but the liabilities of the firms are referred to the fields of dissipative non-conservative forces. The numerical

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value of econophysical gravitational acceleration ***g*** *is found and is equal to* ***5,65*** *and is coincident with the value of econophysical temperature* ***K=5,65*** *of the "mixture of gases" that is the analogy of ABCXZ marketing analysis and has the meaning of generating power of revenues of one stock article per day and is the same for all national currencies. [1]*

Keywords: *Econophysical kinetical energy, Econophysical potential energy, inventory, dissipative and conservative forces, econophysical gravitational acceleration.*

1. Introduction

Physics is the natural science that studies matter, its motion, and behavior through space and time. So, physics studies the general laws of nature and explains phenomena with appropriate patterns using mathematical methods. The traditional question of physics is: why does this phenomenon happen? And the answer is given according to the appropriate model. The question arises logically, but why physics? What physics, which is a very widespread science with modern new compartments, is not enough of its own domain? Surely, the development of physics has reached such limits that it is now becoming interdisciplinary. The human being always at different historical stages is accustomed to observing phenomena in nature and studying them in detail, to explain why these phenomena occur and the cause of their defense. So, namely physics is called science that deeper insight studies the essence of all things in the Nature, Society and Economics. Logically, we can ask ourselves in the following way, since physics explains the essence of all things, then it really does explain everything like: historical evolution of society and eventually statistical repetition of some historical processes, economic phenomena, periodical physic-statistical variations of some market processes described by analogical physical laws, etc.

Physics aims to observe the given phenomenon, and as a result of observation, the quantitative mathematical apparatus is performed, the final result of which is the quantitative law that contains the numerical parameters describing the given phenomenon. Therefore, *econophysics can be defined as a new multidisciplinary philosophical scientific orientation that studies the general laws of the evolution of the economical and social processes by the application of physics –mathematical and statistical methods of the integrative system of philosophical and economical sciences.*

Like physics, econophysics can also contains the similar chapters like econophysical mechanics, econophysical thermodynamics and statistics, electricity, optics, atomical econophysics, etc.

The gravitational model that is referring to mechanics is a model of international trade in international economics that, in its traditional form, predicts bilateral trade flows based on the economic sizes and distance between two units. The model was first introduced in economics world by Walter Isard in 1954. [2] The gravity model estimates the pattern of international trade. While the model's basic form consists of factors that have more to do with geography and spatiality, the gravity model has been used to test hypotheses rooted in purer economic theories of trade as well. [3]

This paper suggests applying the gravitational model to the microeconomical systems of stocks in order to obtain such quantitative parameter that describe the process of selling and in such a way gives the estimation of inventory for various intervals of time in concordance with seasonal character of supply-demand process.

2. Theoretical description of gravitational model for microeconomical systems of stocks

2.1. The stock reserve (inventory) as the analogy of material body situated in the field of gravitational forces

The stock reserve (inventory) can be considered as the analogy of the material body with the mass M that posses the potential energy due to of the gravitational force F_{gr} and this analogy is represented on Figure 1.

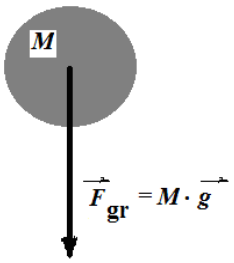

Figure 1. The analogy of the stock reserve (inventory) with the gravitational force F_{gr}

The value of the mass M is calculated as the difference between the price of selling and the prices of dealers. The conception of econophysical

mass is developed consequently in various papers [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15].

One of the law of mechanics is the law of conservation of energy related to the fields of potential forces and the statement of this law is that the total energy which is the sum of kinetical and potential energy of material body is constant with time. Related to the markets of stocks this one is that the stock reserve is considered as the material body with the mass M situated in the field of potential forces. This field of potential forces is described by gravitational acceleration g. The gravitational acceleration of the bodies that are falling on the surface of the Earth is g = 9,8 m/s^2. Reaching the surface of the Earth the speed is maximal (it means that the potential energy is transformed totally into the kinetical energy). Related to the stock reserve of the stock markets also similarly is explained as: the potential energy (the stock reserve) is transforming into kinetical energy (expressed as the terms of the revenues). The aim is to find the value of econophysical (economical) gravitational acceleration. The gravitational force is proportional to the mass of the body with the condition that the acceleration is constant and related to this condition then this dependence has linear function. The general form of this linear dependence is represented below on the Figure 2.

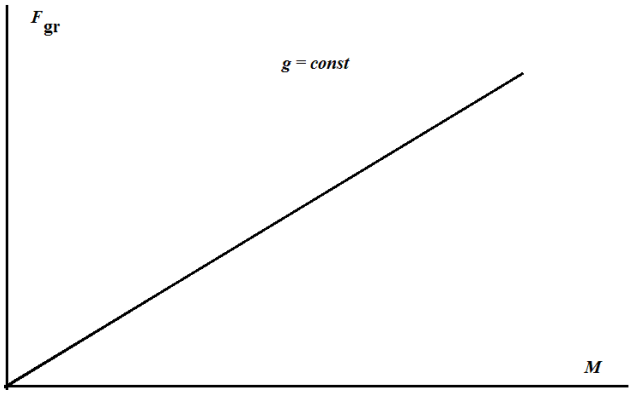

Figure 2. The general theoretical form of the linear dependence of gravitational force F_{gr} upon the mass of the body M at the constant value of gravitational acceleration g.

2.2. The stock reserve (inventory) as the system of material particles situated in the field of potential forces

The mechanical law of conservation of energy in the fields of potential conservative forces states that potential energy E_{pot} is transformed

consequently into kinetical energy E_{kin}, and the sum of potential energy and kinetical energy remains constant all time in these fields.

$$E_{pot}(t) + E_{kin}(t) = E_{tot}(t) = const. \quad (1)$$

This expression (1) is valid in the case when the friction and the resistant forces are neglected or are approximated to zero.

Referring to econophysics, this expression (1) means that the stock reserve is transformed consequently into the revenues. So, the kinetical energy is related to the revenues but the potential energy is related to the stock reserve. The friction forces are neglected meaning that other types of payments are absent, or other types of payments related to salaries, services, rents *etc*. are neglected or absent in comparison with the revenues. The initial value of stock reserve can be restored when a part of revenues are used to pay to the distributors (dealers) in order to restore the initial value of the stock reserve. So, the fields of conservative potential forces are related to the payments to the dealers, but the payments related to salaries, services, rents *etc*. are referred to the fields of dissipative non-conservative forces. Assets of the firms (or microeconomical systems) [16] are referred to the fields of conservative potential forces but the liabilities of the firms are referred to the fields of dissipative non-conservative forces. Frictional forces are non-conservative forces and principally these forces were studied in the papers [17], [18], [19].

The stock reserve can be considered as the system of N material particles that posses a potential energy of gravitational force. The potential energy of this system is the sum of all potential energies of each particles constituents of this system. (Fig. 3) The consumers (customers) of the services and goods have an amazing property to attract these material particles due to of the presence of the gravitational field that they possess and in such way they satisfy their material and spiritual needs – an important property of supply-demand processes. These customers are considered as the zero level of potential energy that is such level where the potential energy is zero and is transformed totally into kinetical energy (it means that the customers pay money during the purchase). The conceptions of the notions of kinetical and potential energies in econophysics were developed in various scientifical papers [20], [21], [22], [23], [24], [25], [26], [27], [28], [29], [30].

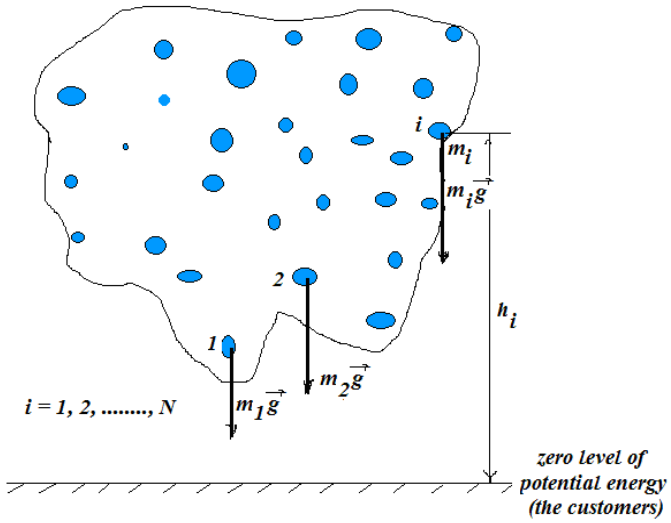

Figure 3. The stock reserve (inventory) as the system of material particles situated in the field of potential forces.

Each particle has the mass m_i and are situated at the heights h_i. The masses m_i are the values of the differences between the prices of selling and the prices of dealers of the respective one packed products. The heights h_i from econophysical point of view are the quantities of packing products of each stock article. The conception of the coordinates and the heights of material points related to their quantities was developed in the scientifical papers [31], [32], [33], [34], [35]. Each particle posses the potential energy:

$$E_{pot_i} = m_i \cdot g \cdot h_i. \tag{2}$$

3. Results of the gravitational model

3.1. The results of the values of masses of material body

In order to check the linear dependence represented on Figure 2 is necessary to calculate the mass M_0 for the each name of the stock article as shown in the Table 1.

Table 1.
The calculation of the values of masses M_0

1	2	3	4	5	6	7	7a
Name of the stock article	Quantity of packing products	Prices of dealers of one packing product	Prices of dealers	Prices of selling of one packing product	Prices of selling (the force F_0)	The mass of one packed product Mo (the difference between the values of **5** and **3**)	The real mass of items $M_{o\,real}$
			The column **3** is multiplied by column **2**		The column **5** is multiplied by column **2**		The column **7** is multiplied by column **2**

The dependence between the values of the columns 6 and 7a – (F_0=f(M_{0real})) is shown on the Figure 4.

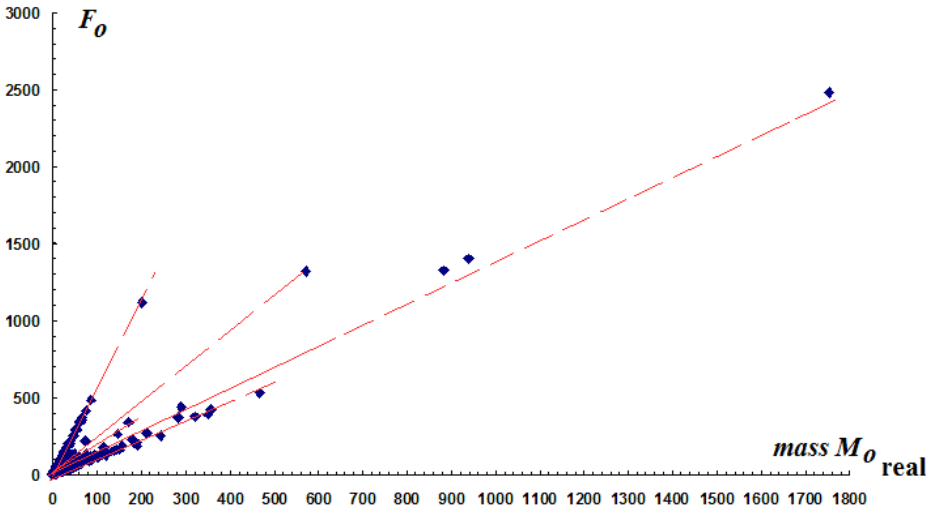

Figure 4. The dependence of the prices of selling of each stock article (gravitational force F_0) upon the mass *Mo*.

The linear segments with various slopes that are shown on the Figure 4 denote the fact that the inventory as a complex system with various stock articles is not homogenous. It means that the stocks are not homogeneously distributed by supply-demand processes of customers. More demand and slowly demand stocks are explained by ABC rating marketing analysis. It is expected that the more demand stocks have the big

slope of linear dependence of Figure 4 and slowly demand stocks have small slope.

If the values of M_{oreal} and Fo are consequently added then the subsystems of inventories with the mass M are created consequently and the dependence $F_{gr}=M.g$ is checked by the following dependence which is represented on Figure 4.

The calculation of the cumulative masses M is represented on the Table 2.

Table 2.
The calculation of the values of masses M
(Continuation of the Table 1)

8	9	10	11
Cumulative masses - *M*	**Cumulative forces - Fgr**	**ln (Fgr+1)**	**ln M**
Consequently sum of the values M_0 from 7-th column	Consequently sum of the values F_0 from 6-th column	The values of natural logarithm of the cumulative forces ***F*** plus one	The values of natural logarithm of the cumulative masses ***M***

The graphic of the Figure 5 is not almost a line with the same slope. It is slowly differentiated by five segments with various slops of linear segments corresponding to the rating groups of the stocks by ABC marketing analysis.

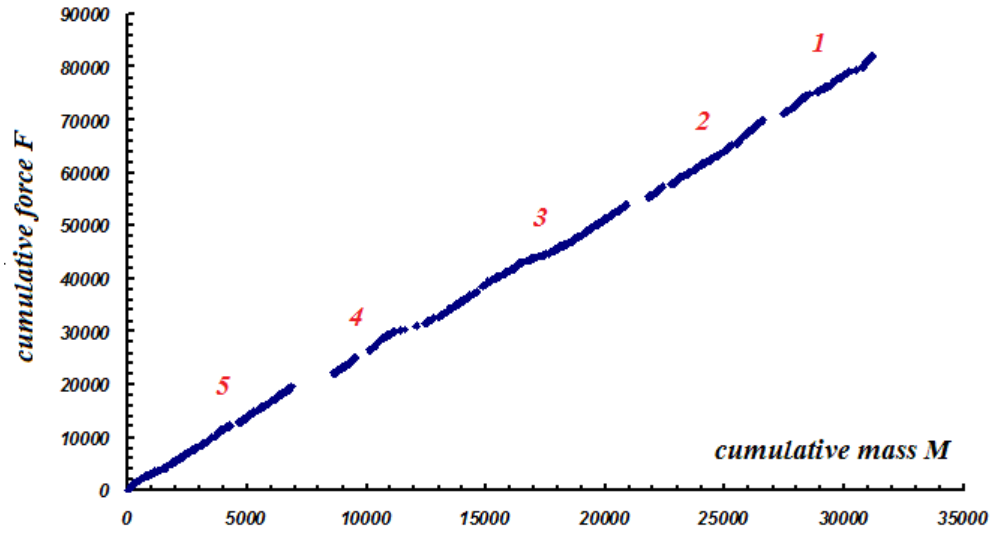

Figure 5. The experimental confirmation of the dependence $F_{gr}=M.g$.

In order to have more exact result of the determination of econophysical gravitational acceleration g it would be better to apply a special procedure of linearization by the application of natural logarithm. So, the natural logarithm of $F_{gr}=M.g$ is:

$$\ln F_{gr} = \ln M + \ln g. \tag{3}$$

And the expression (3) is similar to the general form of the linear dependence as:

$$y = ax + b \tag{4}$$

$$y \equiv \ln F_{gr}; \quad ax \equiv \ln M; \quad \ln g \equiv b. \tag{5}$$

One peculiarity is important to mention regarding the expression (3). This peculiarity is related to the zero value of F_{gr} and $\ln 0 = -\infty$. In order to exclude this extreme case it would be better to have such expression related to $F_{gr}+1$ and $ln(0+1) = 0$, and for the more bigger values of F_{gr} then the natural logarithm is:

$$\ln\left(F_{gr}+1\right) \cong \ln F_{gr}. \tag{6}$$

The question related by the value of the mass M when F is increased by the value 1 is answered by next relation:

$$F_{gr}+1 = (M+x)\cdot g; \quad \Rightarrow \quad F_{gr}+1 = Mg + xg; \quad \Rightarrow \quad xg = 1; \quad \Rightarrow \quad x = \frac{1}{g}. \tag{7}$$

So, the final expression is:

$$F_{gr}+1 = \left(M + \frac{1}{g}\right)\cdot g = M\cdot g + 1 \approx M\cdot g. \tag{8}$$

And the natural logarithm of the expression (8) is:

$$\ln\left(F_{gr}+1\right) = \ln M + \ln g. \tag{9}$$

The graphic of the function $\ln\left(F_{gr}+1\right) = \ln M + \ln g$ is represented on Figure 6.

The value of econophysical gravitational acceleration g is determined from the graphic by $\ln\left(F_{gr}+1\right) = \ln g = 1.7739,$ so the value of g is:

$$g = e^{1.7739} = 5.89. \tag{10}$$

This value of g for the entire inventory could be related surprisingly somehow with that quantitative parameter K_{ABCXZ} =5.65 of ABC marketing analysis.

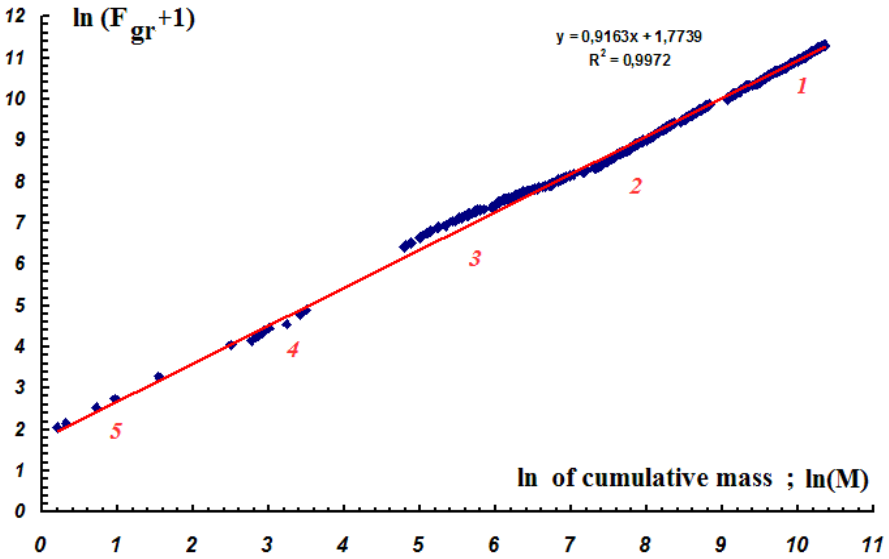

Figure 6. The experimental confirmation
of linear dependence of $\ln(F_{gr}+1)=\ln M+\ln g$.

The rating coefficient of the stock K_{ABCXZ} =5.65 which is found by ABC rating marketing analysis for the entire sold inventory is such quantitative characteristic of this analysis that describes the average turnover during a day from one stock article. The combining of the obtained value of gravitational acceleration g with the value K_{ABCXZ} gives such average value <K>:

$$< K >= \frac{K_{ABCXZ}+g}{2}=\frac{5.65+5.89}{2}=5.77. \qquad (11)$$

The relative error of this gravitational acceleration related to K_{ABCXZ} is found by:

$$\varepsilon=\frac{|< K >-g|}{< K >}\cdot 100\%=\frac{|5.77-5.89|}{5.77}\cdot 100\%\cong 2\%. \qquad (12)$$

So, the important concluding statement of econophysical gravitational acceleration is that this value g is the average turnover from one stock

article during a day. The theoretical aspects about the sense of econophysical gravitational acceleration are described in [11], [12].

3.2. Results of potential energy

Each particle has the mass m_i and posses the potential energy:

$$E_{pot_i} = m_i \cdot g \cdot h_i. \tag{13}$$

The values of masses m_i of one packed product are shown on the Table 3.

Table 3.

The calculation of the values of masses m_i

1	**2**	**3**	**4**	**5**	**6**	**7**	**7 a**
Name of the stock article	Quantity of packing products – ***hi***	Prices of dealers of one packing product	Prices of dealers	Prices of selling of one packing product	Prices of selling (the force F_0)	The mass Mo (the difference between the values of **6** and **4**)	The mass $\boldsymbol{m_i}$ (the difference between the values of **5** and **3**)
			The column **3** is multiplied by column **2**		The column **5** is multiplied by column **2**		

The total potential energy of the entire system with the condition that $g = const$ within the limits of the volume of this system is calculated as:

$$E_{pot} = \sum_{i=1}^{N} E_{pot_i} = g \cdot \sum_{i=1}^{N} m_i h_i = g \cdot < m > \cdot N. \tag{14}$$

Here $<m>$ – average mass of one packing product; N-quantity of packing products of the entire system.

Similarly, if subsystems with consequently increasing of the values N are created (cumulative values of N) then the consequently increasing values of potential energies are obtained.

The process of excluding of limit case $\ln 0 = -\infty$ for the expression (14):

$$E_{pot} + 1 = g \cdot < m > \cdot (N + x) = g < m > N + g < m > x \tag{15}$$

$$x = \frac{1}{g < m >}. \tag{16}$$

Then the natural logarithm of the expression (15) gives:

$$\ln(E_{pot}+1)=\ln\left(g<m>\left(N+\frac{1}{g<m>}\right)\right)\cong\ln(g<m>N)=\ln(g\cdot<m>)+\ln N \tag{17}$$

The experimental confirmation of the linear dependence of the Expression (16) is represented on Fig. 7

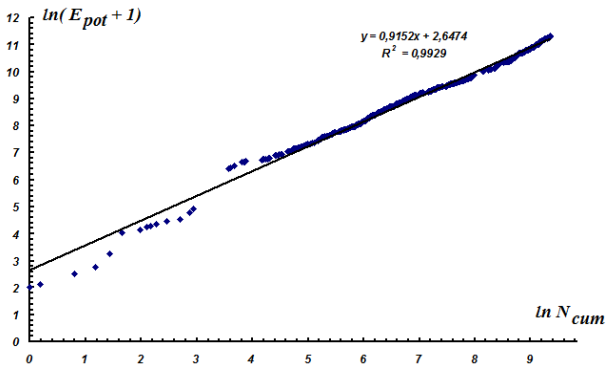

Figure 7. The dependence of $\ln(E_{pot}+1)=f(\ln N)$

Such linear dependence of Figure 7 gives the possibility to find the value <*m*> of entire system with the condition that $g = const.$ The correlation calculation that is represented on Figure 7 shows that

$$\ln(g\cdot<m>)=2.6474 \tag{18}$$

$$g\cdot<m>=e^{2.6474}=14.117\,;\qquad<m>=\frac{14.117}{5.77}=2.44. \tag{19}$$

The regarding of the expression (14) will give the possibility to find the value *g* by the natural logarithm of this one:

$$\ln\left(E_{pot}+1\right)=\ln g+\ln\left(\sum m_i h_i\right). \tag{20}$$

The graphic of the function $\ln(E_{pot}+1)=f\left(\ln\left(\sum m_i h_i\right)\right)$ is shown on Figure 8.

The correlation calculation that is represented on Figure 8 shows that $\ln g = 1.7739$ and absolutely coincides with the value of the Figure 5 and the respective value of g is $g = e^{1.7739} = 5.89$.

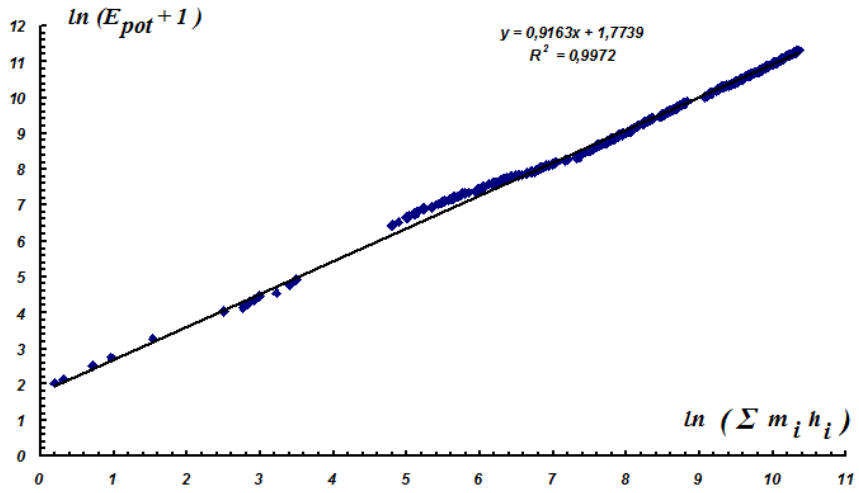

Figure 8. The dependence of $\ln\left(E_{pot}+1\right)=f\left(\ln\left(\sum m_i h_i\right)\right)$.

The calculated value of econophysical gravitational acceleration has the great importance for the real understanding of the generating power of revenues of stocks and it plays an important role the planning of the inventory for respective interval of time, that is a criterion of best supply and respective demand processes of microeconomical activity.

4. Discussion

Economics as a very large science that uses pure mathematical methods in its own manner can proper explain the processes and every time the question is appeared, why econophysics? Perhaps, this new branch of science that is an interdisciplinary and philosophical science in its own manner has more interesting description that could give the answer more deeply for various processes both in economics and Society and the Life. The suggested gravitational model leads to the idea that the human being is the "center of gravitational field" around which this field has the value of gravitational acceleration **g=5,65**. It is important to mention that the value of econophysical temperature of the model of ideal gas is ***K≈g*** [1]. Also it is important to mention that this parameter [1] is not dependent on the value of national currency. This statement was emphasized in [1].

5. Conclusions

The proposed model of gravity in microeconomic systems will serve as a criterion that the stock which is regarded as a material body that is located in the gravitational field possesses potential energy or potentially generating income in accordance with the purchasing power of the customers and respectively demand and supply processes.

This suggested gravitational model serves as a criterion of demand process, that is a process described by special chapter of economy – microeconomics.

In such way a new science ends up being relatively young that is named econophysics, which contains the quantitative parameters that are characteristic of both physics and economy.

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