

# Financial Heat Machine

Andrei Khrennikov<sup>1</sup>, Sergei Kozyrev<sup>2</sup>

## Abstract

We consider dynamics of financial market as dynamics of expectations and discuss such a dynamics from the point of view of phenomenological thermodynamics. We describe financial Carnot cycle and financial analogue of heat machine. We see, that while in physics perpetual mobile is absolutely impossible, in economics this may happen under some conditions.

**Key words:** thermodynamics, financial market, Carnot cycle, perpetual mobile, Maxwell's demon, the second law of thermodynamics.

In econophysics different analogies between economics and thermodynamics were discussed (see, for example, [1]-[5]). In this work we want to discuss the analogies between thermodynamics and financial market.

We start with the statement that financial market works with objects which have virtual, or better to say, cognitive nature (see, e.g., [6]-[9]). These objects are expectations of the market participants about say prices of shares of some company. We insist that this object has no direct relation to something existing in physical reality (while indirect relation is quite possible). Expectations, of course, are related to what the company produces, but we can not say that this relation is fixed. This resembles the situation in theory of *disordered systems*: energy  $H[\sigma, J]$  of the state  $\sigma$  of the system has no definite dependence on the state but also depends on the sample parameter  $J$  (see [10]).

In other words, the dynamics of the financial market is the dynamics of expectations. In this note we discuss this dynamics from the point of view of *phenomenological thermodynamics*. We will not discuss the question how this phenomenological thermodynamics can be justified from the microscopic point of view.

## 1. Financial Carnot cycle

We consider the situation when we have the shares of some company, characterized by the price  $p$  and the volume (number of shares)  $v$ .

We discuss the dynamics of the market when the number of sold shares is equal to  $V_1$  and the price is equal to  $P_1$ . So our starting point is characterized by the pair  $(P_1, V_1)$ . Then we consider the market dynamics when the expectations of the price grow to  $P_2 > P_1$ , but (for simplicity) no new shares are emitted and sold and the market arrives to the point  $(P_2, V_1)$ . We do not discuss the method of achieving this rise of expectations.

Then we start to sell shares at the fixed price  $P_2$ , and sell such volume of shares that the total volume becomes equal to  $V_2$ . For simplicity, we assume that the price of shares will be fixed during this process. So, we arrive to the point  $(P_2, V_2)$ .

Then the *market crash is performed*: the price of shares falls from  $P_2$  to  $P_1$ . Thus we arrive to the point  $(P_1, V_2)$ .

Then we perform reemission of shares at price  $P_1$  reducing its volume to  $V_1$ .

Thus we arrive to our starting point  $(P_1, V_1)$ .

What will be the result of all these four processes? Namely, the result of the cycle:

1. Rise of the price  $(P_1, V_1) \rightarrow (P_2, V_1)$ .
2. Then sale at high price  $(P_2, V_1) \rightarrow (P_2, V_2)$ .
3. Then market crash  $(P_2, V_2) \rightarrow (P_1, V_2)$ .

<sup>1</sup> Doctor of Sciences, Prof., International Center for Mathematical Modelling in Physics and Cognitive Sciences, University of Växjö, Sweden.

<sup>2</sup> Institute of Chemical Physics, Russian Academy of Science, Moscow, Russia.

4. Finally, reemission at low price  $(P_1, V_2) \rightarrow (P_1, V_1)$ .

The result will be the profit

$$\Delta A = \Delta P, \text{ where } \Delta P = P_2 - P_1, \Delta V = V_2 - V_1.$$

The picture described above is obviously the equivalent of the *Carnot cycle in thermodynamics*, which describes say steam engine. The price  $p$  is the analogue of pressure, and the volume of the market (number of shares)  $v$  is the analogue of volume. The profit  $A$  is the analogue of work (or energy). If we will continue these physical analogies, money will be the analogue of vapor. Therefore, if one would be able to influence expectations of financial market participants, then he would be able to do profits using the financial Carnot cycle described.

## 2. Financial perpetuum mobile

To get better understanding let us discuss the standard steam engine from thermodynamic point of view. In steam engine we have boiler, cooler, and the cylinder where the Carnot cycle (in the idealized case) takes place.

The cylinder in our language is the analogue of financial market. What are the analogues of the boiler and the cooler (without which steam engine will not work)?

Boiler is something which used to heat the expectations of the market participants and to increase the price. We propose to use mass media and other sources of financial influence as the analogue of boiler. If one will be able to manipulate the expectations of market agents independently on the real situation with the actives of the company (to cheat market agents), this will be the analogue of perpetuum mobile. We see, that while in physics perpetuum mobile is absolutely impossible, in economics this may happen sometimes. But in fair economics there should be correspondence between market expectations and situation with the actives of the company. In our language this means that one has to put some fuel into boiler.

The role of cooler will be again played by mass media, which in this case will distribute negative information.

The important point here is the possibility of economic perpetuum mobile for those who can control communications (or for those who control the ones who control communications). While in real economy, of course, one has to put some fuel into the engine (to produce some real goods and services), the reaction of stock market and the increase of prices of shares can be considerable higher than changes in real productivity. This shows that financial market indeed works as economic perpetuum mobile, where capital is created and destroyed without considerable changes in productivity. This also shows that thermodynamical analogies in economy are incomplete.

## 3. Financial Maxwell's demon

Let us discuss this in more details. Since in the situation mentioned above one obtains profit due to using the difference in prices during the market cycle, which means that he sells and buys exactly when it is profitable, this market agent works as the Maxwell's demon, and the mentioned perpetuum mobile will be the perpetuum mobile of the second type (which breaks the second law of thermodynamics). The standard objection against the Maxwell's demon is that this demon should be in *thermal equilibrium with the environment*, and therefore it can not use thermal fluctuations of the environment in order to extract energy from the environment: it will itself has thermal fluctuations, and due to these fluctuations the demon will make mistakes, which will equilibrate possible gain of energy. But in economy the Maxwell's demon looks quite possible. If demon will have the temperature which sufficiently lower than the temperature of environment, then number of mistakes which it makes will be low and the demon will be able to organize a flow of energy from the system. In economy temperature, which describes fluctuations, or noise in the system, corresponds to information on the market situation. It is quite possible, that some market agents will be more informed than the others. In this case these agents will be able to use their in-

formation to reduce fluctuations in their shares and act as Maxwell's demons – to extract profit from the market.

We insist that this shows the way to extract systematic profit, *that will not vanish after time averaging*. From physical point of view this corresponds to the fact that each new important information decreases the effective temperature of the market agent, and if he will be able to perform the afore mentioned Carnot cycle (or, at least, considerable part of the cycle) before this new information will become common, this market agent will be able to work as a demon of Maxwell and extract systematic profit from the market.

Moreover, since financial market is a complicated nonlinear system, some market players will be able to organize afore mentioned Carnot cycles in financial market. In this case they will have necessary information on these cycles and therefore will be able to extract profit from the cycles (if the price of organization of the cycle is less than the possible gain in the cycle, or, in other words, if the effectiveness of the financial heat machine is higher than the dissipation).

## References

1. J. A. von Neumann, Review of Economic Studies, 3, 1-9 (1945).
2. M. Lichnerowicz, Annales de l'Inst. H. Poincare (1970).
3. B. Cimblaris, Economy and thermodynamics. Economy and Energy, N.9, 1-9 (1998).
4. J. L. McCauley, Physica A, 329, 199-212 (2003).
5. J. L. McCauley, Self-financing, replicated hedging strategies (an incomplete analogy with thermodynamics). Preprint.
6. J. Soros, The alchemy of finance. Reading of mind of the market. J. Wiley and Sons, Inc., New-York, 1987.
7. P. Ormerod, The death of Economics. J. Wiley and Sons (1997).
8. O. A. Choustova (2001). 'Pilot wave quantum model for the stock market', Quantum theory: reconsideration of foundations. Proceedings of the International Conference in Växjö, June 2001. Ed. A. Khrennikov. Series Math. Mod. in Phys., Eng., Cogn. Sc., 2, 41-58 (Växjö University Press: Vxj).
9. Yu. Khrennikov, Information dynamics in cognitive, psychological and anomalous phenomena. Ser. Fundamental Theories of Physics. Kluwer, Dordrecht (2004).
10. M. Mézard, G. Parisi, M. A. Virasoro, Spin glass theory and beyond, World Sc. (1987).