# Chapter 1.4.

## MARKET CONCENTRATION IN THERMODYNAMIC APPROACH

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**Abstract.** *Real markets are not perfectly competitive as is assumed by the neoclassical theory of economics. The unidirectional process of progressive concentration of capital which can be observed on many markets encourages to refer to the only law indicating irreversibility of real phenomena, that is the second law of thermodynamics, and the category of entropy. The thermodynamic approach is consistent with the general systems theory and the evolutionary perspective and can be applied in the field of economics as it is in other disciplines.*

*The aim of this paper is to start a discussion on a new interdisciplinary interpretation of processes related to market concentration. It is argued that because of the markets being open systems market concentration tends to increase and appropriate entropy measures tend to decline.*

*The first two parts of this paper are mostly empirical and present examples of the application of entropy and competition gradient as the measure of market concentration (based on Fortune's rankings of the 500 largest companies from the United States of America). The third part refers to some chosen thermodynamic, informational and evolutionary aspects of increasing market concentration which is perceived as an effect of the companies struggling with market entropy. This part presents some ideas from the world literature. The final section concludes.*

**Keywords:** *Concentration, Market Structure, Imperfect Competition, Innovation, Evolutionary Economics.*

### Introduction

Real markets are not perfectly competitive as is assumed by the neoclassical theory of economics which generally disregards such issues as heterogeneity of products and companies, imperfect information, barriers of entry, non-price competition, innovative activity or irreversibility of market concentration. The neoclassical economics is based on a general equilibrium theorem, while markets (like other socio-economic systems) are in reality non-equilibrium thermodynamic systems.

As a matter of fact the unidirectional process of progressive concentration of capital which can be observed on many markets encourages the researchers to refer to the only law indicating irreversibility of real phenomena, that is the second law of thermodynamics, and the category of entropy. Obviously, the thermodynamic approach is consistent with the general systems theory and the evolutionary perspective and can be applied in the field of economics as it is in other disciplines.

Markets can be treated as open evolving systems processing information. They consist of collections of elements (economic agents) and relations between them which constitute altogether the structure of the market system. The structure itself determines the functioning of the market – competitive structures allow for a better allocation of resources and higher social efficiency in the economy while concentrated or monopolized structures make it possible to achieve higher profitability and economic efficiency by the dominating companies.

Market concentration (sellers' concentration) is a term typically related to the proportions of shares of the companies in the market but it can be also perceived as a process of achieving higher efficiency thanks to bigger shares in the market. It reflects the degree of control exercised by a small group of companies over a market or another portion of economic activity. Increasing market concentration provides a competitive advantage through exercising increased market power due to spread of fixed costs, exploitation of economies of scale or improvement in managerial efficiency. To some extent the increasing concentration illustrates the irreversibility of investment (including mergers and acquisitions) and innovation.

This paper is an attempt to begin the discussion on a new interdisciplinary interpretation of processes related to market concentration. It is argued that because of the markets being open systems market concentration tends to increase, whereas appropriate entropy measures tend to decline – in other words, process of market divergence dominates over the process of convergence. Reducing market entropy is possible because of operating of competition forces driven by exogenous factors such as motivation.

The first two parts of this paper are mostly empirical and present examples of the application of entropy and competition gradient as the measure of market concentration. They are based on *Fortune's* rankings of the 500 largest companies from the United States of America. However, because of limited data availability they have above all just a demonstrative character. The third part refers to some chosen thermodynamic, informational and evolutionary aspects of increasing market concentration which is perceived as an effect of the companies struggling with market entropy. The final section concludes.

## Entropy as the measure of market concentration

In the economic literature entropy is often used to measure concentration – that is to illustrate the extent to which the market is dominated by the biggest companies. The entropy measure of concentration follows the formula:

$$H = -\sum_{i=1}^{n} p_i \log p_i$$

where: $p_i$ represents the share of each company and $n$ is the number of companies in the market.

The entropy measure of concentration is being used apart from other concentration measures, such as four or eight biggest companies concentration ratio. One of the advantages of this measure is its sensitivity with reference to small companies.

The application of entropy as the measure of market concentration will be in short demonstrated on the basis of *Fortune's* rankings of the 500 largest (in terms of revenues) companies from the United States of America (Fortune 500). As in this case entropy is calculated with use of decimal logarithm, it is expressed in hartleys. The maximum theoretical value of entropy amounts to:

$$H_{max} = \log 500 = 2{,}699 \text{ hartleys}$$

and refers to a hypothetical situation in which all of the 500 largest companies have equal revenues. The lower the empirical value of entropy, the greater the inequalities in revenues distribution.

The results for the years 1954-2008 are presented on Chart 1.

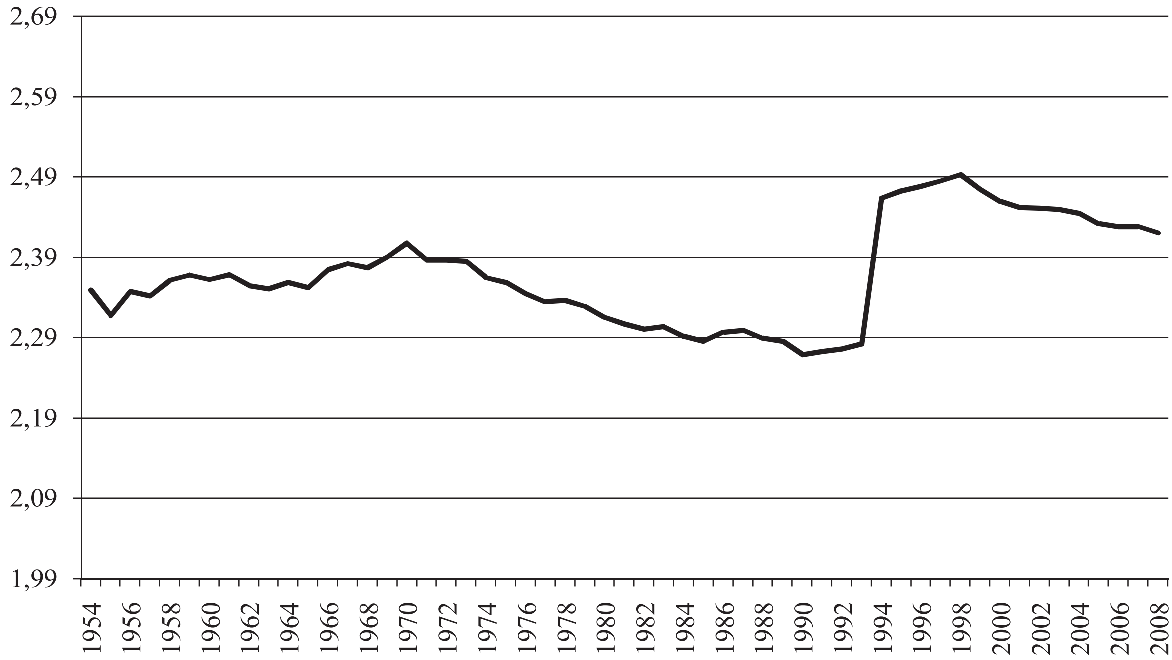


Chart 1. Empirical entropy calculated for the revenues of the 500 largest companies from USA in 1954-2008
Source: author's calculations based on *Fortune's* directories from 1955-2009.

Sudden jump in entropy value in 1994 corresponds with a change in methodology of creating the rankings – since then not only manufacturing but also service companies have been taken into account. This methodological change precludes from tracing trend of entropy for the whole period but at the same time it allows for an illustration of the significance of changing the frontier of a system as regards its entropy.

Entropy is an extensive variable and its value does not depend on size of the isolated system which means that including more companies in *Fortune's* rankings should not affect the entropy values if revenues of service companies were distributed in the same way as those of manufacturing companies. As it is not the case one should look for the influence of other parameters depicting differences between both groups of companies.

Apart from this change there were three decades in the years 1954-2008 characterized by decreasing values of entropy which reflects increasing concentration among investigated companies. It would be interesting to compare the fluctuations of the value of entropy on different markets within the business cycle. Recessions may lead to increasing market concentration because they favour large companies capable of taking over other companies. On the other hand expansions are somehow more democratic and are characterized by growth of size and investment activity of most companies which reduces market concentration.

Lower level of entropy in a system can be achieved only by exploitation of opportunities from the environment. For example, the companies from *Fortune's* rankings may compete by shifting costs on their consumers.

One can also analyze differences of concentration between smaller groups of investigated companies. Values of empirical entropy for five groups (100 companies per group) in the years 1954-2008 are presented on Chart 2, while average empirical entropy amounts to the values calculated in Table 1. These values can be compared with maximum entropy:

$$H_{max} = \log 100 = 2 \text{ hartleys}$$

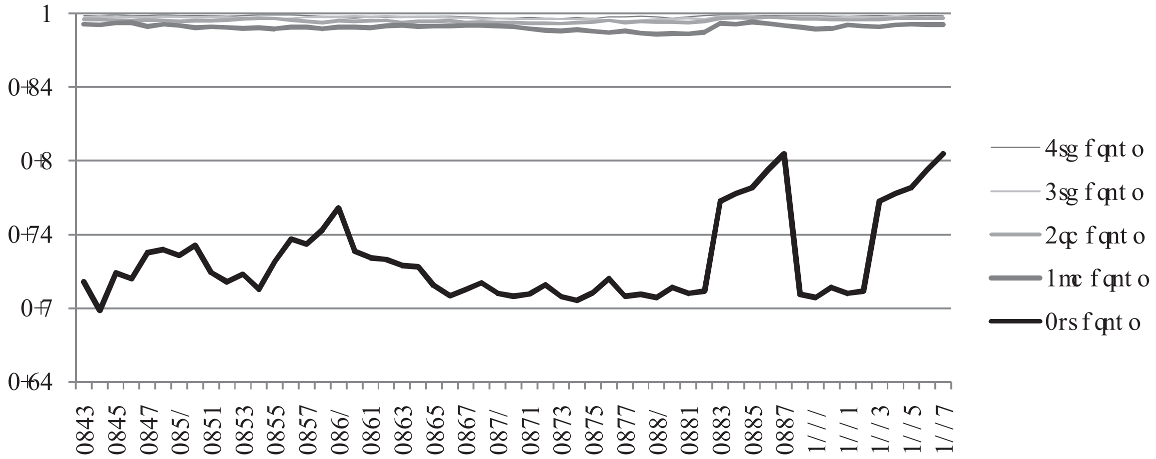

Chart 2. a) Empirical entropy calculated for the revenues of the five groups of 500 largest companies from USA in 1954-2008.

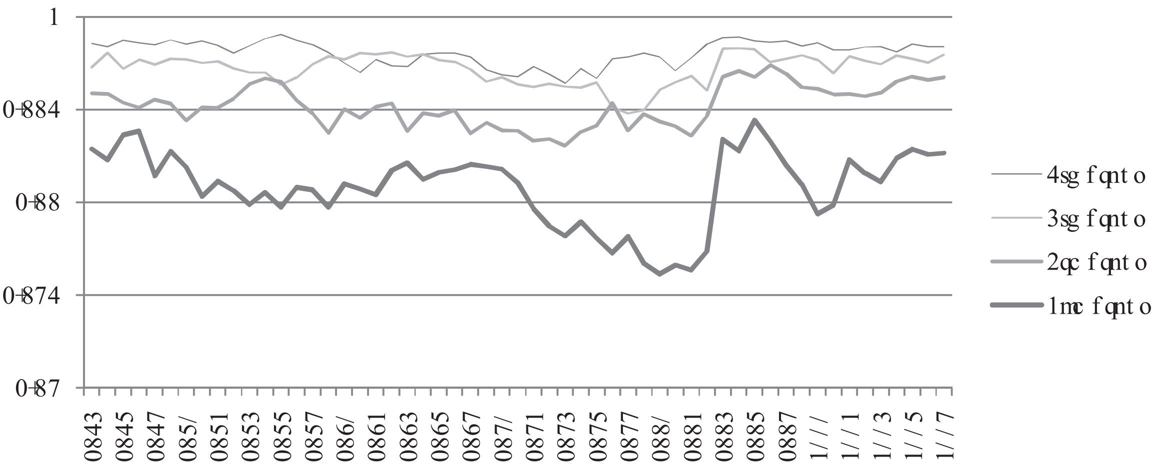

Chart 2. b) Tenfold enlargement of the top part of chart 2a) area.
Source: as above.

Table 1. Average empirical entropy calculated for the revenues of the five groups of 500 largest companies from USA in 1954-2008

| Group of companies | Average entropy (in hartleys) |
|---|---|
| $1^{st}$ (1-100) | 1,833 |
| $2^{nd}$ (101-200) | 1,991 |
| $3^{rd}$ (201-300) | 1,995 |
| $4^{th}$ (301-400) | 1,997 |
| $5^{th}$ (401-500) | 1,998 |

Source: as above.

As could be expected, variety measured with entropy is not the same in these five groups of companies. Indeed, consecutive groups are characterized by higher values of entropy and less significant differences regarding revenues.

The thermodynamic analysis of market concentration allows for a new interpretation of emergence of concentrated and even monopolized market structures. Such structures are a rational response to the challenge of the second law of thermodynamics operating in the area of economic activity. Concentrated and monopolized structures are more stable than competitive ones, because once formed (by exploitation of opportunities and less adapted economic agents) they allow for greater waste in terms of extensively conceived entropy. As a matter of fact, the more efficient the company is in exploitation of its environment (economic efficiency is related to higher profitability and possibilities of company growth), the less efficient it has to be during its functioning. In other words, the more available resources, the less incentives for rational management. And finally, structures that do not require so much effort to maintain them are more stable in time.

**Entropy of money, competition gradient and market concentration**

In thermodynamic approach money can be treated as an equivalent of energy – its capability to perform work depends both on its quantity and quality (concentration). For instance, an amount of \$ 1,000,000 allows for investment in a more significant venture than 1,000 amounts of \$ 1,000, not to mention 1,000,000 amounts of \$ 1.

The dispersion of money related to its spending can be expressed in entropy-like formula:

$$s = \log \frac{M}{1+m}$$

where $s$ is the unit entropy of a given amount $m$ (calculated for monetary unit) and $M$ is the money supply (the total entropy of amount $m$ equals $S = m \cdot s$). So the more dispersed money is, the greater its unit entropy (Ksenzhek, 2007, p. 50).

In consequence, one can define a thermodynamic efficiency of spending each monetary unit:

$$\eta = 1 - \left( \frac{s_1}{s_2} \right)^{\rho}$$

where $\eta$ stands for unit efficiency, $s_1$ for unit entropy of the initial (more concentrated) state, $s_2$ for unit entropy of the final (more dispersed) state and $\rho$ is a parameter depicting efficiency of transformation of money ($\rho = 0$ for a totally inefficient mechanism and $\rho = 1$ for and ideal mechanism of transformation that is not spending any money for performing its internal functions) (Ksenzhek, 2007, p. 52-53).

Some hypothetical values of unit entropy and unit efficiency of money are presented in Table 2.

Table 2. Unit entropy and unit efficiency of money depending on its concentration, total supply of money and efficiency of transformation of money

| Amount of money $m$ | Total supply of money | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $M = 10^9$ units | | | | $M = 10^{12}$ units | | | |
| | unit entropy $s$ | unit efficiency $\eta$ (%) | | | unit entropy $s$ | unit efficiency $\eta$ (%) | | |
| | | $\rho = 0,4$ | $\rho = 0,5$ | $\rho = 0,6$ | | $\rho = 0,4$ | $\rho = 0,5$ | $\rho = 0,6$ |
| 1,000,000,000 | 0,00 | 100,00 | 100,00 | 100,00 | 3,00 | 42,57 | 50,00 | 56,47 |
| 100,000,000 | 1,00 | 58,48 | 66,67 | 73,24 | 4,00 | 35,56 | 42,26 | 48,27 |
| 10,000,000 | 2,00 | 45,21 | 52,86 | 59,44 | 5,00 | 29,54 | 35,45 | 40,86 |
| 1,000,000 | 3,00 | 35,56 | 42,26 | 48,27 | 6,00 | 24,21 | 29,29 | 34,02 |
| 100,000 | 4,00 | 27,70 | 33,33 | 38,53 | 7,00 | 19,39 | 23,62 | 27,63 |
| 10,000 | 5,00 | 20,95 | 25,46 | 29,72 | 8,00 | 14,97 | 18,35 | 21,59 |
| 1,000 | 6,00 | 14,97 | 18,35 | 21,59 | 9,00 | 10,87 | 13,40 | 15,85 |
| 100 | 7,00 | 9,56 | 11,84 | 14,00 | 10,00 | 7,03 | 8,73 | 10,36 |
| 10 | 7,96 | 4,79 | 5,96 | 7,10 | 10,96 | 3,56 | 4,44 | 5,29 |
| 1 | 8,70 | 1,35 | 1,69 | 2,01 | 11,70 | 1,01 | 1,26 | 1,51 |
| 0 | 9,00 | 0,00 | 0,00 | 0,00 | 12,00 | 0,00 | 0,00 | 0,00 |

Source: author's calculations based on: O. Ksenzhek (2007), Money: Virtual Energy. Economy through the Prism of Thermodynamics, Universal Publishers, Boca Raton, Florida, p. 54.

The considerations above present a yet another justification for processes of market concentration. Companies, like other economic entities, try to receive as much money as possible – not necessarily more than they possess but more than possess other entities, because it guarantees the highest possible unit efficiency of money spent for investment. Therefore, one should expect hierarchical market structures as a result of competition between companies striving for the highest possible efficiency of money

In this interpretation revenues of companies exhibit Pareto-like distribution:

$$y = \alpha\, n^{-\beta}$$

where $n$ is the order number of a given company in terms of revenues (the lower the order number of the company, the higher its revenues), parameter $\alpha$ represents the revenues of the company ranked first and the exponent $\beta$ is a parameter depicting the inequalities concerning revenues distribution (Ksenzhek, 2007, p. 82). If the parameter $\beta = 0$, all companies would receive the same revenues. Higher values of $\beta$ indicate growing inequalities (Chart 3). It is also worth mentioning that the value o parameter $\beta$ is independent of the distributions being expressed in absolute or relative numbers (with respect to the average).

Taking into account that the range of values, both of the revenues and the order numbers of the companies, may be very wide, one can plot these values in double logarithmic scale (Ksenzhek, 2007, p. 77). Chart 3 presents hypothetical distributions characterized by a single value of parameter $\beta$ that are graphically illustrated as monotonically descending line with constant inclination.

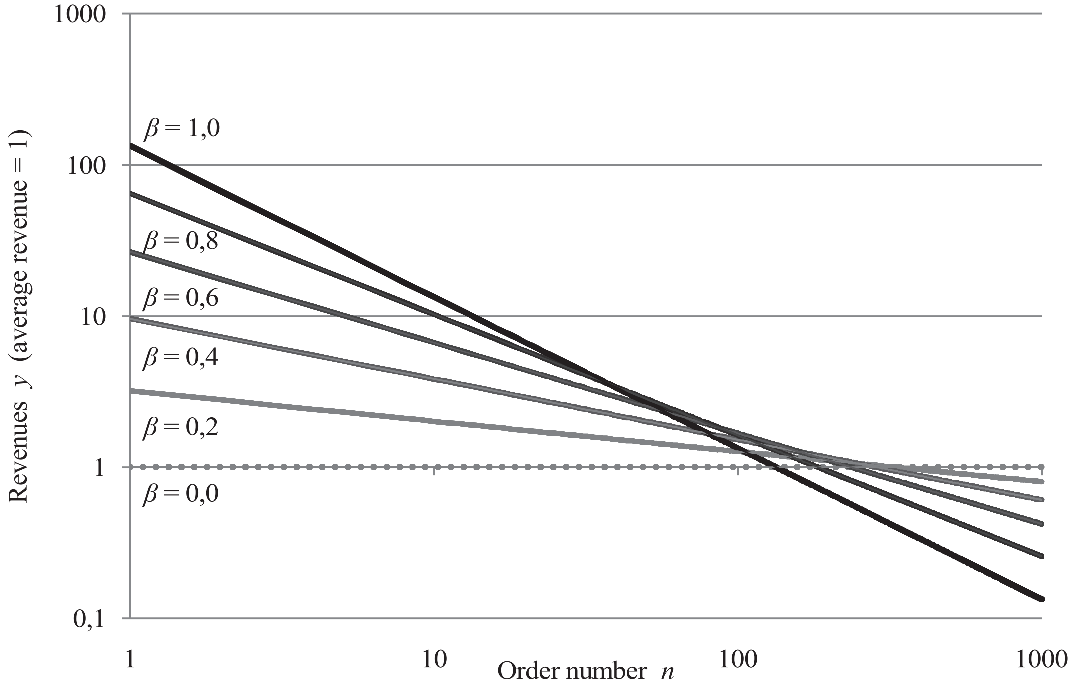


Chart 3. Theoretical distributions of revenues for different values of competition gradient (parameter $\beta$) calculated for 1000 companies
Source: author's elaboration based on: O. Ksenzhek (2007), Money: Virtual Energy. Economy through the Prism of Thermodynamics, Universal Publishers, Boca Raton, Florida, p. 82.

Parameter $\beta$ can be called a competition gradient, because it depicts the level of competitive tension in a market (Ksenzhek, 2007, p. 84). For instance, a shift from 1000$^{th}$ to 100$^{th}$ position (or from 100$^{th}$ to 10$^{th}$ position) means more than six times greater revenues for $\beta$ = 0,8, while for $\beta$ = 0,2 revenues would be only one and a half greater. So in the former situation companies would be much more motivated to expand than in the latter.

In reality, such a shift may guarantee a tenfold growth of revenues as the value of parameter $\beta$ may exceed unity (Chart 4). The application of competition gradient as the measure of market concentration will be once again demonstrated on the basis of *Fortune's* rankings of the 500 largest companies from the United States of America (Fortune 500).

To some extent Chart 4 mirrors Chart 1 – it reflects similar tendencies as well as the described earlier change in methodology of creating the rankings.

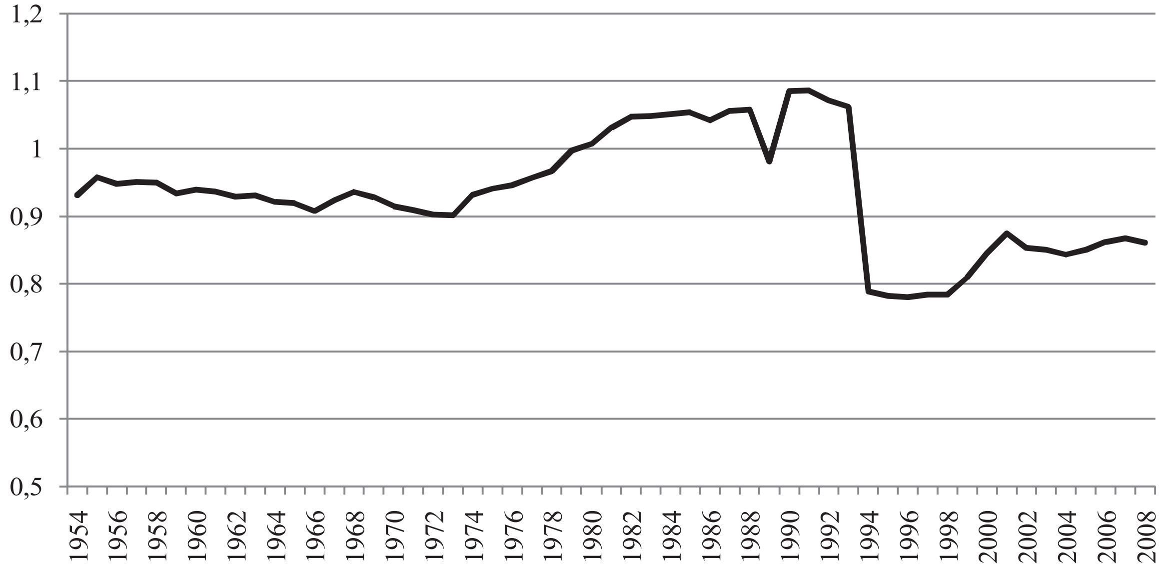


Chart 4. Competition gradient (parameter $\beta$) calculated for the revenues of 500 largest companies from USA in 1954-2008
Source: author's calculations based on *Fortune's* directories from 1955-2009.

However, one has to be aware that real distributions of revenues are not perfectly homogeneous in terms of competition gradient (parameter $\beta$). Indeed, the distributions seem to be flatter for low order numbers and steeper for high order numbers (Chart 5).

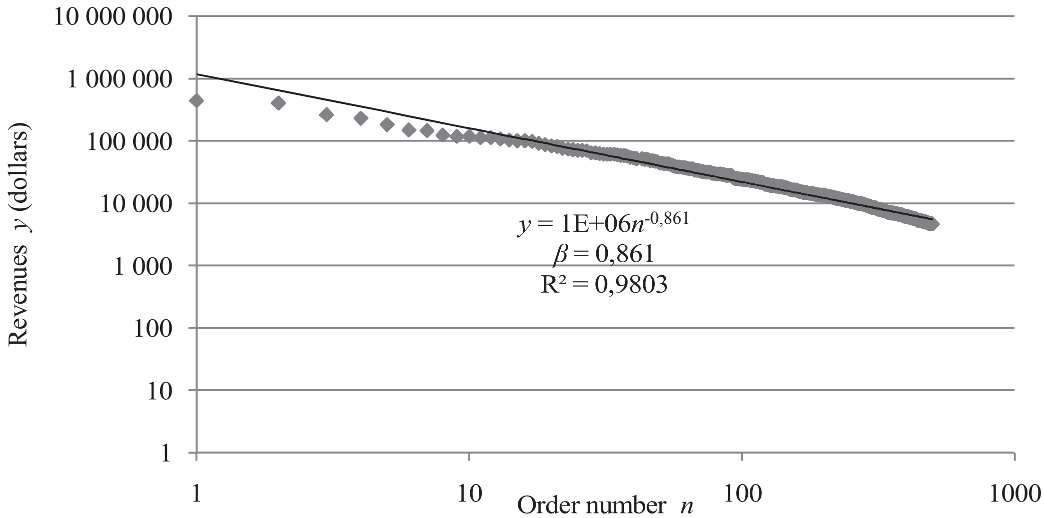


Chart 5. a) Real distributions of the revenues of 500 largest companies from USA in 2008 (most recent example)

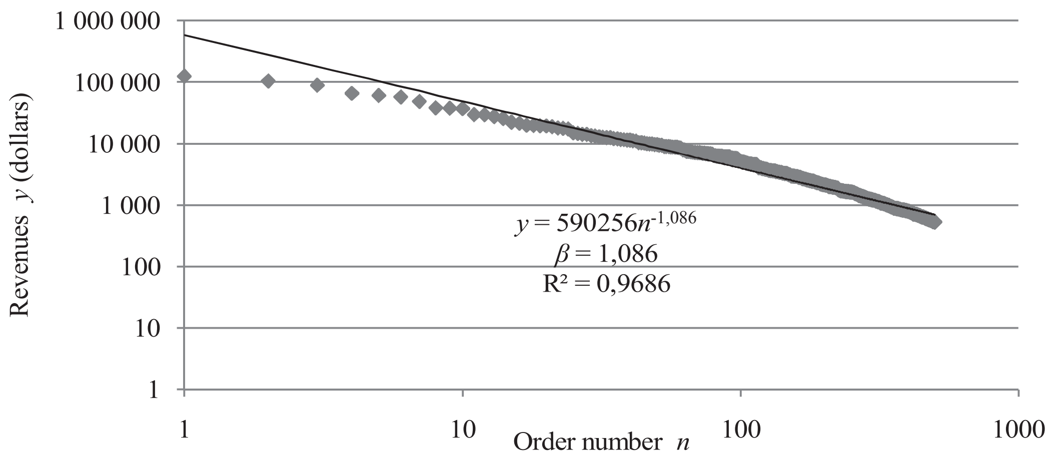


Chart 5. b) Real distributions of the revenues of 500 largest companies from USA in 1991 (example characterized by the highest value of parameter $\beta$)
Source: as above.

It is also important to emphasize that disproportions between highest and lowest revenues can be related to the size of the market. As the revenues are generally inversely proportional to the order number in hierarchy, a bigger market would be characterized by a more complex structure with much higher revenues of the biggest companies in comparison with companies present in a smaller market. This statement is consistent with the statistical version of the second law of thermodynamics.

In other words, the highest revenue depends strongly on the size of the market and the competition gradient, while the lowest revenue only on the competition gradient (Ksenzhek, 2007, p. 89). This justifies the observation that the biggest companies in the world are not only the main driving force of globalization but also the most important beneficiaries of this process.

**Market concentration and struggle with entropy**

Basically, the history of a worldwide discussion on the application of thermodynamics in the field of economics began with the statement that the entire economic life feeds on low entropy and that low entropy is a necessary condition for things to have value and be useful (Georgescu-Roegen, 1971, p. 277-278).

According to the second law of thermodynamics, diffusion in all systems is spontaneous and there is a tendency for them to become homogeneous. Therefore not only biological but also economic systems in order to exist need to extract low entropy from the environment to compensate for continuous dissipation. In this case the possibilities of extraction of low entropy depend on institutional structures which should be able to adapt to the changing environment in the course of time (Chen, 2005, p. 32).

Such structures incur certain costs. For example, if one social group or economic system achieves a higher level of development than others, the second law of thermodynamics inflicts that this situation cannot last long, unless institutional barriers are established to prevent the free migration of people or other forms of interaction which could lead to equalization of levels of development. In general, economic systems that possess more natural or institutional resources tend to be more exclusive and enforce property rights more firmly (Chen, 2005, p. 73).

Referring again to the problem of value one can state that for a given product value is inversely related to the number of its producers. More precisely, according to the entropy theory of value, the unit value of a product can be calculated as:

$$V = -\log_b P$$

where $b$ is the number of producers and $P$ is the abundance of the product.

If both parameters are very high, the market is highly competitive, but the value of the product is very low. Thus the entropy theory of value proposes that goods produced in almost perfectly competitive markets are of low economic values, while goods produced by monopolists or oligopolists are valued highly. So one of the sources of economic value may lie in imperfectness of competition and market concentration (Chen, 2005, p. 48).

The development of market concentration can be related to the process of market growth. When a new market emerges, it is characterized by a high degree of uncertainty. For this reason there are a lot of small companies in the market which are very flexible because of their low fixed costs. As a market grows, the degree of uncertainty becomes lower and if fixed costs are increasing on a growing market, variable costs will decrease rapidly. Generally, in the mature market large companies that incur higher fixed costs achieve competitive advantage over small companies and tend to dominate mature market structures (Chen, 2002, p. 3). Due to the accumulation of capital and increase of investment in large companies it is possible to reduce variable costs significantly. This in turn allows the dominating companies to reduce the product prices and to eliminate small companies characterized by high variable costs.

One can also assume that there are companies producing the same product with the same production technique but have different unit costs and different unit profitability. Each company tries to invest all its profits in capacity expansion and to fix a price that corresponds with the growth of its capacity and growth of its market. If there was unlimited flow of information and consumers' reactions were perfectly elastic, there would be a perfectly competitive market with one price. However, in reality, each company may try to set a different price that is lower than others' prices in the same proportion so that its unit costs are lower. In consequence, companies with lower unit costs can grow faster and thus account for an increasing share of the total market, until a company or a group companies with the absolutely lowest costs will dominate the market (Metcalfe, 2005, p. 401-402).

On average, even without price reductions profitable companies grow while unprofitable contract, which makes the group of more profitable companies account for a growing share of the economic activity in the market. The distribution of company sizes evolves over time: market structures that are originally highly competitive tend to show growing concentration (concentrated structures appear to be more stable).

The mechanism of this evolution can be explained by the fact that successful innovations are rewarded with excess profits which enable a faster growth of profitability in relation to other companies. Thus successful innovations may lead to a highly concentrated industry structure when a company implements them frequently enough or is able to secure a dominant position for a longer period of time (Nelson, Winter, 1982, p. 308). However, the growth of concentration is not inevitable, if companies are imitating rather than innovating. The harder it is to imitate the innovations of a successful company, the longer it will dominate the market. But if imitation is relatively easy, no matter how significant was the initial success, this competitive advantage will not last long (Nelson, Winter, 1982, p. 311). For this reason innovations providing long-lasting competitive advantage are called innovations of low entropy and those which are diffusing quickly because of imitation – innovations of high entropy. Value of a given innovation depends mostly on the pace of its diffusion in the market. Entropy in this interpretation illustrates the erosion of competitive advantage, that is the loss occurring because of voluntary or involuntary sharing of information (Gastle, 2002, p. 21-23).

Furthermore, large companies have a higher probability of coming up with an innovation, because it is proportional to the company's R&D spending which in turn is usually related to the size of the company. Large companies spend more on R&D than small companies (Nelson, Winter, 1982, p. 310).

Even if all the companies were equally sized and had the same R&D policy and theoretically the same probability of coming up with a successful innovation, in practice they would not have the same outcomes. There is an element of chance in innovative activity leading to diversity of productivity and profitability levels as well as growth rates of the companies in the market and as a consequence – to the market concentration.

Both great variance of a successful R&D outcome and rapid pace of technological change along with unlimited possibilities of company growth (that can make further success more likely) mean stronger tendencies for concentration to develop even in a market initially composed of many equal-sized firms (Nelson, Winter, 1982, p. 311).

Selection process rewards the currently efficient companies but does not guarantee that they have the necessary capability to innovate continuously in an outstanding manner. This is why it is important that many dispersed and independent sources of innovation existed in the market. So a particularly dangerous consequence of the market concentration is the limitation of the number of innovators and in the worst case – the monopolization of the sources of knowledge in the hands of a single company in the market (Metcalfe, 2005, p. 418).

It has to be emphasized that there are some significant costs incurred by the largest companies in the market. They require more resources to sustain themselves and therefore are vulnerable to (and risk collapsing because of) environmental changes such as resource depletion or low market demand. They also suffer from uncertainty and high legal costs as other economic agents are motivated to extract wealth concentrated in these companies. Furthermore, there are high costs of internal coordination of such complex systems (Chen, 2002, p. 3).

There is yet another factor that makes it difficult for the largest companies to adjust to the changing environment. Small companies have more flexible structures enabling easy accommodation of innovations but this can be disruptive for complex structures of large companies. Because of their firm structures the largest companies sometimes cease to be active and successful innovators (Chen, 2002, p. 10).

A company cannot dominate any market, if it is not the most efficient in extracting low entropy. However, maintaining such a position on a growing market is very costly in entropy terms. This is one of the reasons for which functioning markets cannot reach equilibrium.

From the evolutionary perspective one can state that there are processes of variation, selection, imitation and elimination on the market. Markets provide incentives for satisfying needs of the population or shifting resources from unfit units toward fit ones. Thus they can be interpreted as evolutionary search mechanisms which are more efficient in disequilibrium due to innovations than rationally planned systems in equilibrium. While the neoclassical economics refers frequently to the perfect efficiency of markets in equilibrium, the thermodynamic approach treats market efficiency as a more relative concept. Perfect market efficiency probably does not exist, but even if it did, it would not be reached because of the disequilibrium nature of markets. Markets are like thermal machines – they can never be 100 percent thermodynamically efficient. Although not perfectly, markets are efficient at resources allocation which is implied by their computational capabilities of networks processing information (Beinhocker, 2006, p. 294-295).

Generally, the number of states of a network grows exponentially with the number of its elements. In consequence, as a network grows in size, the amount of information it can process and the potential for novelty also increase exponentially creating a new informational kind of economies of scale (different form traditional economies of scale relating cost and volume). For example, a network with 10 elements can be in $n^{10}$ possible states, while a network with 100 elements can be in $n^{100}$ states (where $n$ represents the number of possible states per element). The space of possible states for a ten times greater network is a few dozen orders of magnitude greater. So the difference between a company employing 10 people and a company employing 100,000 people is only four orders of magnitude in terms of the number of employees but many more orders of magnitude greater in terms of complexity and capacity of processing information and creating novelty (Beinhocker, 2006, p. 148-149).

For this reason companies, markets and other human economic organizations can be perceived as networks growing in size over time. These networks allow not only to produce the same products cheaper and in a larger quantity (as traditional economies of scale would explain), but also to implement more and more innovations. It is the development of technology that enables greater scale of economic cooperation and creates more potential for innovations.

However, there are important diseconomies of scale driven by the degree of connectedness in such a growing network. The more connections per element of a network, the bigger the discrepancy between the pace of growth of number of elements and number of connections – the number of interdependencies can grow much faster than the network itself. As a result it is considerably more probable that a positive change in one part of the growing network will have a negative effect in another part (Beinhocker, 2006, p. 150-151).

This explains the gradual loss of adaptability in densely connected networks and the persistent growth of bureaucracy. Thus there are two opposing forces affecting growing organizations – the informational economies of scale (related to increase of degrees of possibility) and the diseconomies of scale from the accumulation of conflicting constraints (related to decline of degrees of freedom). In other words large companies encounter more opportunities than small companies, but those opportunities involve severe trade-offs (Beinhocker, 2006, p. 152).

It has to be once again emphasized that processes of market concentration, as well as diffusion of innovations or growth of dominating companies, networks and bureaucracy are irreversible. From the thermodynamic point of view markets are not perfectly efficient and do not reach the state of equilibrium. In this context application of the concept of entropy would be appropriate, however, apart from its use as a measure of concentration entropy is quite distantly related to discussed economic categories.

**Concluding remarks**

This paper was an attempt to compose a background for linking together problem of market concentration with dynamic and irreversible changes, market structures and networks, purposeful activity and chance, innovations of high and low entropy and imitation, market efficiency and market equilibrium, entropy and efficiency of money, economic value and number of producers. The shape of economic evolution depends mostly on the relations between high fixed cost systems which are dominating the markets in a stable environment and low fixed cost systems which are more flexible and successful in volatile and uncertain market conditions.

Market evolution and increasing market concentration can be perceived as a result of purposeful action aimed at efficient extraction of low entropy from the environment (which is accompanied by different capabilities in this field) as well as an element of chance when one of the companies turns out to be a successful innovator. On the other hand market concentration can be treated as a source of economic value.

The thermodynamic approach to the problem of market concentration can be very fruitful but it requires deeper elaboration, development and above all – putting in order such concepts like entropy with its energetic and informational interpretations. Further exploration and research on the irreversibility and thermodynamic efficiency of mechanisms of market concentration would be also desirable.

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