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DETERMINING MARKET CONCENTRATION

Romualdas Ginevičius[1], Stasys Čirba[2]

Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-10223 Vilnius, Lithuania
E-mail: [1]romualdas.ginevicius@ adm.vtu.lt

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Abstract. One of the major problems associated with market concentration is its quantitative evaluation. In fact, a concept of the concentration curve is used in almost every case.

The suggested measures may be classified as discrete or accumulative values. All of them are of limited accuracy because the first ones take into account only a part of the concentration curve, while the second values cannot adequately describe the situation in the market.

The accuracy of the above measures can be determined based on the total difference in the relationship between the carriers of particular attributes in the market and the value calculated for them by the market concentration formula based on the suggested measure. The above measure yields the best result in determining the total difference.

Keywords: market concentration, measure of concentration.

1. Introduction

To integrate into the economic system of Western countries, the enterprises and companies of the new member-states of the European Union (EU) should become equal partners of the firms of these countries. They can achieve this if they are competitive. In theory and practice, competitiveness is often associated with a market share. This is an integral result of stable enterprise expansion. To retain and enlarge a market share, an enterprise should adapt to the continually changing environment. The adaptation should not be only passive, i. e. aimed at holding the position attained. The economic development of the country results in the market growth. Therefore, enterprises should also widen the scope of their activities and use advanced methods, otherwise, they will bankrupt. Winning a larger market share is becoming a basic strategic principle of achieving enterprise competitiveness. Only by keeping the rate of growth not lower than that of the market growth in the country, companies can enlarge or at least retain their market share [1, 2].

Hence, market competition compels enterprises to increase their activity, i. e. to concentrate it. Both external and internal factors stimulate concentration because holding and expanding the market share largely depends on increasing enterprise productivity, i. e. on improving implements of production as well. On the other hand, empirical evidence suggests that introduction and use of advanced methods and technical equipment requires the concentration of production. Therefore, market competition engenders the need for concentration as a production growth condition. When the scale of production is increasing, its efficiency, as well as enterprise competitiveness, are also growing (Fig 1).

Concentration processes can be considered from various perspectives. First, unlimited market concentration results in monopolization threatening small enterprises. Moreover, the main principle of market economy, implying that a customer can freely choose a seller, can be violated, the possibilities of new providers of goods and services to act on the market can be restrained, etc.

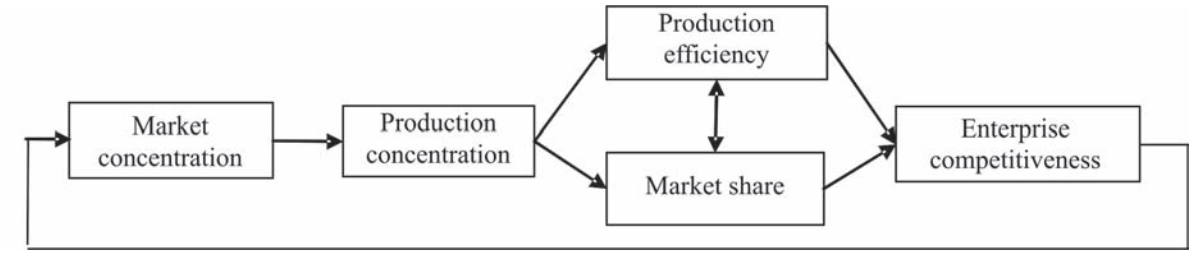

Fig 1. The relationship between market concentration and enterprise competitiveness

On the other hand, concentration increases the efficiency of production, strengthening enterprise position in the market. The same applies to international competition because only large-scale production can compete with foreign firms on the internal market, as well as winning foreign markets and increasing the competitiveness of a particular state. Therefore, the analysis of concentration (especially market concentration) is of great practical and theoretical importance today. One of the main problems is also associated with quantitative evaluation of the level achieved.

2. Some problems of concentration measure accuracy

Recently the number of investigations dealing with the problem of concentration has grown considerably. Each of them offers a measure of this process. The variety of the suggested measures shows that an ideal version has not been found yet. The suggested measures have their strengths and weaknesses and vary in the accuracy of measure.

Before considering the concentration measures in detail, they should be systematized.

In fact, in all cases, concentration measurement is based on the concept of the concentration curve. This curve can be obtained by plotting market players (attribute carriers) on the abscissa of the coordinate system in the descending order of magnitudes, while laying off on the ordinate the respective cumulative values (sums of attribute carriers) [3]. A concentration curve characteristic of the market presented by four market players, having 40 %, 30 %, 20 % and 10 % of the market share, respectively, is shown in Fig 2.

Measuring units, based on the concept of the concentration curve, are either discrete or cumulative [4]. The first ones account for only a part of the points on the concentration curve. The values corresponding to these points are used directly or indirectly as concentration measures. In the latter case, the values of the points are generalized in various ways according to their significance.

Cumulative measures of concentration account for all values of attribute carriers (AC) found on the ordinate of the concentration curve. Different versions of these measures are obtained by using various schemes of determining AC significance.

The most widely known and used discrete concentration measure is concentration index. It is also based on the concentration curve. In this case, the value *m* of the axis of abscissas, corresponding to the respective ordinate value, is determined. The formula of the

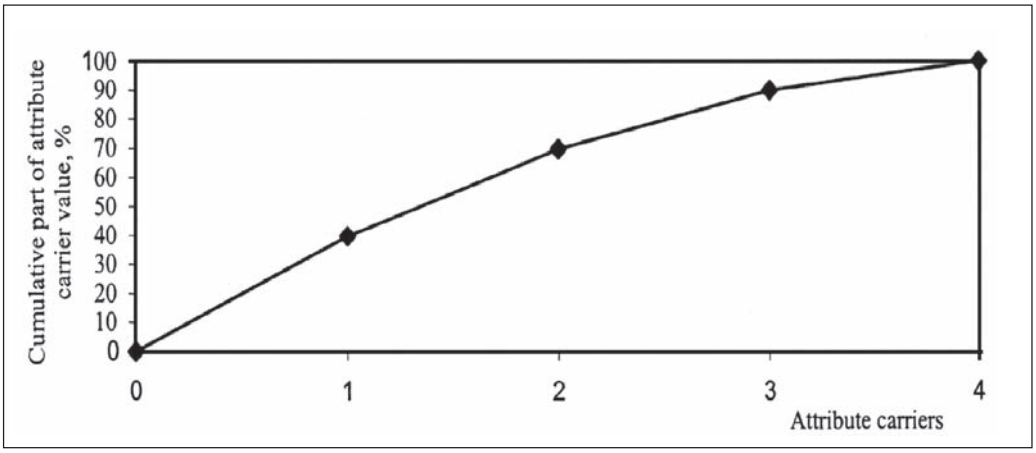

Fig 2. Concentration curve

concentration index is as follows [5]:

$$KI_m = \sum_{i=1}^{m} P_i \ , \qquad (1)$$

where KI_m is a concentration index; m is the m-th attribute carrier; P_i is the *i*-th attribute carrier's relative part in the sum of attributes ($0 \le P_i \le 1$); n is the largest number of the considered attribute carriers ($m \le n$).

This measure is popular for several reasons. First, it is easy to understand. For example, KI_4 = 0,6 means that four largest attribute carriers account for 60 % of the sum of attributes. Second, it is easy to use. To determine the index, only the data on *m* largest attribute carriers' market shares and the sum of attributes should be available. This means that only the first points of the concentration curve should be known. However, in order to determine the largest ACs, the information about other market players should be available, though the data on the sum of small attributes are not required.

The concentration index, as well as its measure, is limited because it shows only one point of the concentration curve. In this case, their sum and various available forms of the curve distribution among *m* largest attribute carriers are not taken into account. To eliminate this drawback, the concentration index relating to *m* attribute carriers arranged in the descending order presents great interest. For some reason (some statistical data are restricted), it is often impossible to calculate the values of KI_1 or KI_2.

The accuracy of the concentration index largely depends on *m.* The analysis of the literature on the problem shows that it is chosen freely. However, to suggest *m* for accurate reflection of the situation in the market, it should be economically grounded. One can hardly find the answer to this question in the literature. To get the answer, the nature of the market should be studied. According to the economic theory, the market can be monopolistic, oligopolistic or uniform [6]. Thus, it is only necessary to determine, for example, what *m* value corresponds to oligopolistic market. In the USA, *m* = 4 is used in this case. On the other hand, the choice of 4, but not of 3 or 5 as in other countries, is not grounded. The use of different *m* values to assess the degree of concentration of the same type of markets makes the international comparison of the concentration index more complicated.

In spite of the above disadvantages, discrete measuring units of concentration possess a significant plus compared with others because they can be determined without considering lots of statistical information. Therefore, these measures allow us to perform a brief analysis of the market structure at small expenses [5].

The so-called Herfindahl index analysis can be used to show the main disadvantages of cumulative units of concentration measurement. This index is obtained by raising to the second degree and summing the shares of the carriers of the sum of all attributes [7, 8]:

$$HER = \sum_{i=1}^{n} P_i^2 \ , \qquad (2)$$

where HER is the Herfindahl index.

To decide if the Herfindahl index can be used, the problem of determining the significance of attribute carriers should be considered. As seen from the formula (2), attribute carriers having larger parts of the sum of attributes are given larger weights, those having smaller parts of the sum are assigned smaller weights. This is naturally obtained when attribute carriers are weighted, i. e. AC values are raised to the second degree. As a result, the relationship between the values of two attribute carriers 2:1 will be changed by the Herfindahl index into, for example, 4:1, while the relationship 4:1 – into 16:1, etc. It follows that the values of HER index depend on large attribute carriers, while small attribute carriers, even if they are great in number, have practically no effect on the result obtained. Therefore, this measure does not property reflect actual market concentration. Moreover, its insensibility to small attribute carriers prevents it from being used in research aimed at determining the influence of small or new market players (attribute carriers) on the market structure. On the other hand, if considering competitiveness, large attribute carriers are the object of attention, and the Herfindahl index yields a sufficiently accurate result.

Another cumulative measure of concentration is the Horwath index [9]:

$$HOR = P_1 + \sum_{i=2}^{n} P_i^2 \, (2 - P_i) \ , \qquad (3)$$

where HOR is the Horwath index; P_1 is a market share of the largest attribute carrier ($KI_1 = P_1$).

When the Horwath index is used, all market players are assigned larger weights than those obtained by applying the Herfindahl's index. The largest attribute carrier is most important because its whole absolute part of the attribute sum is used in a measure. Unlike Herfindahl index, the Horwath index, due to the specific character of AC weight determination, does not tend to accumulate the value in the lower variation interval, ranging from 0 to 1. This helps to avoid the threat of evaluating the actual market concentration as too low. On the contrary, the points tend to accumulate in the middle and upper parts of the interval [5]. This state is balanced by assigning higher weights

to smaller attribute carriers, thus compensating for the domination of the largest carriers.

The Horwath index is not an ideal measure. First, its subdivision into discrete and cumulative parts is not sufficiently grounded. It is not clear why in the discrete part of the formula (3) only one, the largest, attribute carrier is taken into account, rather than, for example, two or three of them. Determination principle of attribute carrier significance in the cumulative part of the formula (3) is also not sufficiently clear because the values for larger attribute carriers range from 1.5 to 2, while for smaller attribute carriers the value is 2.

Another cumulative concentration measure is entropy [10]:

$$ENT = -\sum_{i=1}^{n} P_i \ln P_i , \qquad (4)$$

where ENT is entropy measure.

Determination of attribute carrier weight by entropy measure is based on logarithm rather than on value, as in the case of the Herfindahl index. This results in a decrease of the significance of larger ACs and an increase of the significance of smaller ACs, respectively.

The value of the entropy measure ENT presents information, generally expected when one of all events occurs. The question arises why this concept of the information theory can be applied to concentration measurement. The relation between the extent of competition and entropy is clear in the case of a monopoly because, in the absence of competition, a monopolist need not worry that a customer can choose a product of another manufacturer. When the number of product (service) providers and, thereby, competition is growing, the uncertainty of a particular provider about the customer's choice of his product is also increasing. Moreover, the uncertainty depends on the relative size of the provider as well.

Therefore, entropy can be perceived as a competition measure depending on the market structure and performance and strongly affected by a measure of concentration [11].

The analysis of the entropy measure shows that its theoretical basis is completely different from that of the indices based on the concentration curve. This makes their comparison and interpretation more complicated.

Another cumulative measure of concentration is its exponential index [5]:

$$EXP = \prod_{i=1}^{n} P_i^{P_i} , \qquad (5)$$

where EXP is exponential index of concentration.

A comparison of the Herfindahl and exponential indices revealed only one difference between them. They differ in determining the significance of large and small carriers because the first one is more sensitive to large ACs, while the second – to small ACs. This has a certain influence on their calculation technique. Thus, to determine the exponential index, value distribution of all market ACs should be known, while an approximate, but a sufficiently accurate value of the Herfindahl index can be obtained based on the 'reduced' distribution of the concentration curve. The empirical research of exponential index shows the concentration of the points in the lower part of the intervals ([0:I]) of possible values, similar to the case, when the Herfindahl index is used. The calculated values are usually smaller than the Herfindahl index values. Thus, it is more probable that the actual concentration degree will be estimated intuitively too low.

One more cumulative measure of concentration is the Rosenbluth index [12–14]:

$$ROS = \frac{1}{\left(2\sum_{i=1}^{n} iP_i\right) - 1} , \qquad (6)$$

where ROS is the Rosenbluth concentration index.

According to ROS, ranking of attribute carriers is based on the principle that the higher the total number of ACs, the larger weight is assigned to smaller carriers. Therefore, this index is sensitive to the number of attribute carriers rather than their size. It can be shown that when the share of the dominant AC is more than 50 % of their total share and the number of the ACs is growing, ROS index value is rapidly approaching zero. Thus, despite the clearly monopolistic market structure, the actual market concentration is not properly reflected. Due to different approaches to determining attribute carrier weight by Rosenbluth and Herfindahl indices, there are some differences in their market description. Empirical research shows that the values of indices do not differ much, both in absolute value and rank correlation [12]. Like in the case of using the exponential index, attribute carrier points are accumulated in the lower part of their interval ([0:1]). Therefore, the use of these indices excites apprehension that intuitively determined degree of concentration will be too low. Greater differences between the values of *HER* and *ROS* may also be expected when large ACs are dominant in the market and their total number is large.

Another cumulative concentration measure is GIN index [15]:

$$GIN = \sum_{i=1}^{n} \frac{P_i}{1 + n(1 - P_i)} . \qquad (7)$$

This index aims at the proper, i. e. balanced assessment of two essential market characteristics – the size of attribute carriers and their number. The author of the concentration index believes that all suggested measures (perhaps with the exception of the Rosenbluth index) have the same drawback: they either ignore or pay little attention to the number of attribute carriers, which is one of the main free market characteristics. It is the value reflecting the relation between market players and their customers which is characteristic of market economy. When the number of product (service) providers is growing, the competition is becoming more intense and the provider's uncertainty about the customer's choice of his product (service) is also increasing. It is clear that the uncertainty also depends on the relative size of the provider, therefore, each attribute carrier is reduced by a coefficient reflecting his weight, depending on the number of market players as well.

Discussing concentration indices, their drawbacks observed by other authors [5] were presented. A more thorough analysis revealed even more serious problems associated with their application.

One of the concentration measure properties is that, when any attribute carrier P_i is getting larger, its value should also be increasing. However, the Horwath index HOR and the entropy measure ENT do not satisfy this condition. Assume that we have two P_1 and $P_2 (P_1 = p; P_2 = 1-p)$. In this case,

$$HOR = p^3 - p^2 + 1, \tag{8}$$

$$ENT = -p \ln p - (1-p)\ln(1-p). \tag{9}$$

Graphs, corresponding to the formulas (8) and (9), are presented in Fig 3.

In Fig. 3 we can see that

$\min HOR = HOR(\frac{2}{3}) = \frac{23}{27} = 0{,}852$. Given two equal attribute carriers ($(P_1 = P_2 = 0{,}5)$, other concentration measures assume the value 0,5, with their values increasing when one of the carriers is getting larger, i. e. when $P_1 = 0{,}5$, then,

$$HER(0{,}5) = ROS(0{,}5) = EXP(0{,}5) = GIN(0{,}5) = 0{,}5.$$

As shown in Fig. 3, the maximum value of the entropy measure is 0.69, and the value of this measure is decreasing, when the carrier P_1 is getting larger.

The analysis of the available concentration measures shows another property of these units: when attribute carriers are of the same size, the relative weight of each carrier in the value of measure is the same, being equal to the attribute carrier value. To check if *ROS* index satisfies this condition, let us write:

$$\sum_{i=1}^{n} iP_i = \frac{1+ROS}{2\,ROS}. \tag{10}$$

Relying on the formula (10), we can roughly estimate a relative contribution of each attribute carrier to the index *ROS* value (Table 1). Assume that we have four attribute carriers of the same value, i. e. $P_1 = P_2 = P_3 = P_4 = 0{,}25$. Based on the formula (10), a contribution of attribute carriers to *ROS* value will be determined (Table 1).

Thus, the concentration index *ROS*, unlike other measures, does not satisfy the above condition.

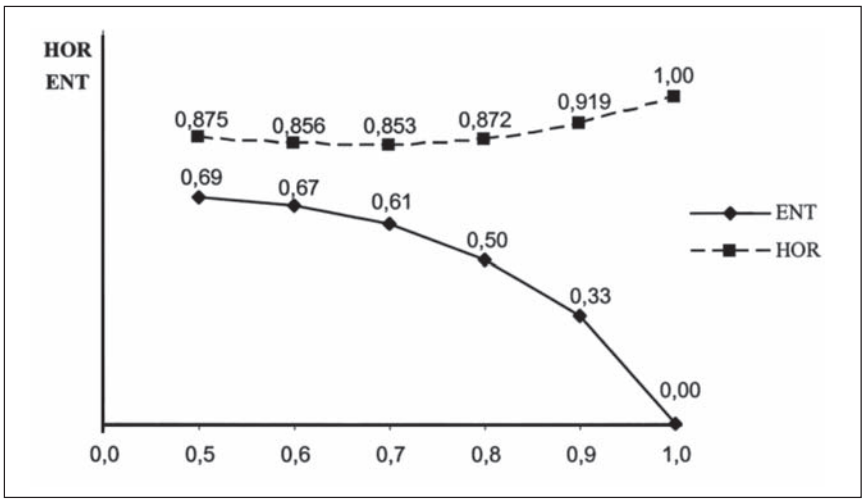

Fig 3. Graphical representation of the Horwath and concentration indices as well as entropy measure, when $n = 2$

Table 1. A relative contribution of attribute carriers to *ROS* value, when $P_i = 0{,}25$

ROS	Carrier values			
	0,25	0,25	0,25	0,25
0,25	Relative contribution of carriers to the index value			
	0,1	0,2	0,3	0,4

3. Assessing the accuracy of market concentration measures

A survey of market concentration measures, based on the scheme suggested in the literature, when all measures are compared with the most widely used Herfindahl index, showed some essential drawbacks of these units, including *HER* index as well. The main disadvantage is associated with structural peculiarities of measures. As a result, a distorted picture of the actual market situation, which can be better or worse (which is often the case) than it really is, can be provided. To consider the problem of the particular measure accuracy, the concepts of actual and estimated, or calculated, market concentration degree should be discussed. Actual market concentration is shown by the relation between the absolute and relative values of the size of attribute carriers. For example, if a hypothetical market, consisting of four attribute carriers, having the absolute values of 40 %, 30 %, 20 % and 10 % and respective relative values of 0,4; 0,3; 0,2 and 0,1, is considered, then, the actual market situation will be expressed as the relation 4:3:2:1. The estimated or calculated market concentration can be obtained by taking the relation characterizing the AC magnitude transformed by using a respective concentration measure formula (Table 2). Unfortunately, only three indices – Herfindahl's (2), expositional (6) and *GIN* (7) can be compared because they allow the relative weight of each attribute carrier to be calculated in the concentration measure formula.

As seen from Table 2, the suggested indices provide various views, differing from the actual market concentration to a certain degree. In this connection, two problems arise. First, to suggest the quantitative expression of the considered measure accuracy. Second, to offer a more accurate market concentration measure because, as shown in Table 1, the available measures are not accurate.

Table 2. The structure of market concentration depending on the formula used in calculation

Concentration measure	Relations between the sizes of attribute carriers			
	Attribute carriers			
	1st	2nd	3rd	4th
Herfindahl index	16,0	9,0	4,0	1,0
Horwath index	21,05	8,05	3,79	1,0
Entropy index	1,59	1,57	1,40	1,0
Rosenbluth index	1,00	1,50	1,50	1,0
GIN index	5,41	3,63	2,19	1,0
Concentration index GIS	3,86	2,79	1,93	1,0

Let us state that the smaller the total difference between the AC size in the market and their relative size calculated by the considered concentration measure formula, the more accurate is a concentration measure in reflecting the actual market concentration (the number and size of attribute carriers) [15]:

$$R_j = \sum_{i=1}^{n} \left| P_i - P_i^* \right|, \qquad (11)$$

where R_j is accuracy criterion of the *j*-th concentration measure; P_i^* is *i*-th attribute carrier's relative size according to the formula of the *j*-th concentration measure.

A concentration measure will be the most accurate when it ideally reflects market situation, i. e. when $R_j = 0$.

Based on the data in Table 1 and formulas (2–7), we will determine the values of the criterion R_j (Table 3).

As seen from Table 3, none of the concentration measures considered are ideal because, for fall of them, the total difference between a relative size of attribute carriers of the market analyzed and their size according to the concentration measure formula is above zero. It can be only stated that *GIN* index is the closest to it, as far as the difference value, which

Table 3. Comparison of the accuracy of concentration measures

Concentration index	Value of concentration index	Relative size of attribute carriers in the concentration measure formula				R
		P_1^*	P_2^*	P_3^*	P_4^*	
HER	0,300	0,533	0,300	0,133	0,033	0,268
HOR	0,644	0,621	0,238	0,112	0,030	0,442
ENT	1,280	0,286	0,282	0,251	0,180	0,263
ROS	0,333	0,2	0,3	0,3	0,2	0,400
GIN	0,266	0,442	0,297	0,180	0,083	0,082
GIS	0,397	0,403	0,291	0,202	0,104	0,018

is approaching zero, is concerned. This is the reason for seeking a more accurate concentration measure.

The suggested size is expressed as "a sum":

$$K = \sum_{i=1}^{n} q_i \,, \tag{12}$$

where $q_i = f(P_i)$, $i = 1, 2, \ldots, n$ and $P_1 \geq P_2 \geq \ldots \geq P_n$.

Let us make a system of equations to search for a measure which is more sensitive to market changes related to the smallest attribute carriers:

$$\begin{aligned}
&\frac{q_1}{K} = (1 - \frac{np}{0{,}5n+1})P_1 = \frac{n+2-np}{n+2} P_1;\\
&\ldots\\
&\frac{q_i}{K} = (1 - \frac{(n-i+1)p}{0{,}5n+1} P_i = \frac{n+2-2(n-i+1)p}{n+2} P_i;\\
&\ldots\\
&\frac{q_n}{K} = (1 - \frac{(n-n+1)p}{0{,}5n+1} P_n = \frac{n+2-p}{n+2} P_n \,.
\end{aligned} \tag{13}$$

Let us divide through each equality, beginning with the second one, by the first equation:

$$\begin{aligned}
&q_2 = \frac{P_2}{P_1} \frac{n+2-2(n-1)p}{n+2-np} q_1;\\
&\ldots\\
&q_i = \frac{P_i}{P_1} \frac{n+2-2(n-i+1)p}{n+2-np} q_1;\\
&\ldots\\
&q_n = \frac{P_n}{P_1} \frac{n+2-p}{n+2-np} q_1.
\end{aligned} \tag{14}$$

Let us substitute the obtained q_i expressions into formula (12):

$$K^* = q_1 + \sum_{i=1}^{n-1} \frac{P_{i+1}}{P_1} \frac{n+2-2(n-i)p}{n+2-np} q_1 \,. \tag{15}$$

Assume that we have two attribute carriers, i. e. $P_1 = \bar{p}$ and $P_2 = 1 - \bar{p}$, while the concentration measure most accurately reflecting market changes is linearly depending on $\bar{p}$. We will get the situation, when $q_1 = p_1^2 = \bar{p}^2$ and $p = P_2 - P_1 = 1 - 2\bar{p}$.

$$K^{**} = \bar{p}^2 + \frac{1-\bar{p}}{\bar{p}} \bar{p}^2 = \bar{p} \,. \tag{16}$$

In the case considered, i. e. when $P_1 = \bar{p}$ and $P_2 = 1 - \bar{p}$, other concentration measures will be expressed as follows:

$$HER = 2\bar{p}^2 - 2\bar{p} + 1; \tag{17a}$$

$$HOR = \bar{p}^3 - \bar{p}^2 + 1; \tag{17b}$$

$$GIN = \frac{4p^2 - 4\bar{p} + 3}{(3 - 2\bar{p})(1 + 2p)}; \tag{17c}$$

Graphical representation of formulas (16, 17a, 17b) and (17c) is provided in Fig 4.

Taking into account that a concentration measure reflects market changes most accurately when it linearly depends on $\bar{p}$, we can make the following changes in the formula:

$$q_1 = P_1^2; \; p = P_{i+1} - P_i \,. \tag{18}$$

Then, the formula (15) will be as follows :

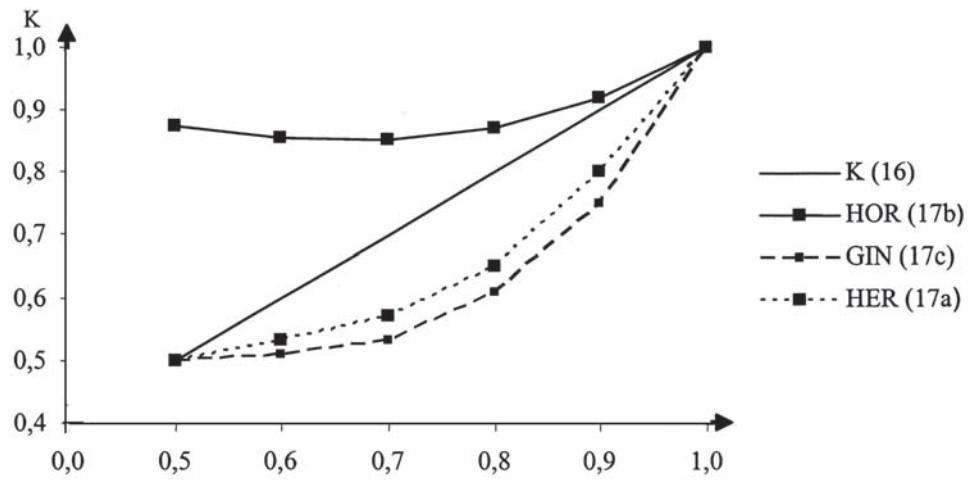

Fig 4. Graphical representation of concentration measures, when $n = 2$

$$GIS = (1+\sum_{i=1}^{n-1}\frac{P_{i+1}}{P_1}\frac{n+2-2(n-i)(P_{i+1}-P_i)}{n+2-n(P_{i+1}-P_i)})P_1^2 . \quad (19)$$

The *GIS* value will be a concentration measure sought.

The respective calculations for the concentration index *GIS* are presented in Tables 2 and 3.

It can be seen from Table 3, that the total difference between the relative size of attribute carriers of the considered market and their size according to the concentration measure formula is the smallest for the suggested measure. This allows us to state that it reflects market situation most accurately compared to other measures and, therefore, can be successfully used in calculations, particularly, in research. The formula (19) seems to be complicated. In practice, indices, which are simple to use, like Herfindahl index, are widely applied. Today, in the time of computers, this problem is not relevant, therefore, the suggested index can be effectively used in practical calculations as well.

4. Conclusions

1. All market concentration measures can be divided into two groups – discrete and cumulative units. Measures of the first group are based on the concentration curve. They are not ideal, accounting only for a limited number of attribute carriers, and not taking into consideration market changes and other factors.

2. The main drawbacks of cumulative market concentration measures are as follows: the index value mainly depends on large attribute carriers and is groundlessly divided into discrete and cumulative parts. Besides, different weights are subjectively assigned to attribute carriers and the number of the considered market players is not taken into account.

3. The index suggested in the present paper accurately reflects market structure, taking into consideration the number of market players, and, therefore, can be effectively used for measuring absolute market concentration.

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