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A Market Concentration Analysis of the Biomass Sector in Romania

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Abstract: The degree of market concentration is an important investigative tool used by competition authorities, as well as any public entity or undertaking that is interested in a specific market. There are several market concentration indices, but the most popular measure for computing the degree of market concentration is the Herfindahl–Hirschman Index (HHI). However, a limitation of this indicator is that its computation requires data on all the entities that are active in a market. Therefore, due to the large number of companies in some specific markets, sometimes it is cumbersome to compute the HHI. The aim of this paper was to develop an algorithm to estimate as accurately as possible the HHI in such cases, so that the degree of market concentration can be identified. An interdisciplinary application of this method on the Romanian biomass sector is presented at the end of this paper.

Keywords: biomass sector; market analysis; renewable energy; resources

1. Introduction

The prosperity of the countries and societies in the European Union (EU) depend on the use of natural sources. The resources include renewables, such as biomass, hydro, wind or geothermal energy and non-renewables, such as metals, minerals or fossil fuels. At the same time, the growing demand for materials in EU countries puts their natural resources at danger. Moreover, it creates pressures on the environment, including biodiversity loss, climate change, soil degradation, scarcity of fertile land and waste accumulation.

Biomass is the most important renewable energy sector and has grown in importance in recent decades. The production of biomass was studied in many recent papers. Fogarassy et al. [1] investigates the efficiency of the pyrolysis and the increase in the quality of gas production from biomass through the optimization of prototype systems. The study concludes that the more accurate dimensioning of the main parts of the gas reactor, the better the quality of the biomass gas output obtained. The efficiency of the biomass production was developed in other studies [2–4]. The studies conclude that the efficient production of biomass has significant benefits for the environment, such as lowering the levels of carbon dioxide. Other studies [5–7] analyzed the increasing importance of the biomass sector in the context of the increasing shares of renewable energy in total energy consumption at the EU level. Their main results are that the increasing use of biomass energy generates sustainable economic growth across the EU.

The investigative measures undertaken by competing authorities often involve the analysis of the relevant market. A starting point for any such analysis must be the assessment of the degree of market concentration, which is the degree to which a small number of firms account for a relatively large percentage of the market. In addition to the information already owned by the authority, the degree of market concentration provides prerequisite data for the market in question. Economic theory indicates a direct link between the degree of concentration in a market and the performance of businesses in that market [8–10]. In addition, the assessment performed on a given market enables the setting of benchmarks relative to the market shares held by the respective market players. An important objective of economic analysis in the field of competition is the development of methodologies and indicators to assess the level of competition in certain markets and economic sectors.

The assessment of competition in economic sectors facilitates the fulfillment of the provisions of competition law and it also interacts with other supervisory and regulatory business [11–14]. The design of the assessment indicators requires the identification of sets of publicly available data or data that can be collected with a reasonable logistical effort, given the best use of human resources and time by the competition authority [15,16]. From the calculation point of view, the indicators of the degree of market concentration can be of two types: absolute indicators and relative indicators [17,18]. Note that, in the case of market concentration indicators, the absolute and relative terms do not have the same meaning in the broad sense of the terms [19]. Here, the absolute indicators refer to indicators that are calculated as weighted sums of the market shares, whilst relative indicators refer to indicators that are calculated as weighted averages of the market shares [20]. Market shares can be expressed in two ways: in percentages or in absolute values. When it is not specified the way in which the market share is expressed, it is assumed that it is expressed in percentage terms. In terms of an economic market with perfect competition, the following elements are relevant for evaluation: the free entry and exit of participants in the market, i.e., there are no barriers to entry/exit from the market and also whether or not the market is fragmented, i.e., there are a many players in the market and each player has a small market share close to zero [21–23]. If these conditions are not met, the market in question is one with imperfect competition. For example, if a small number of entities are active in the market and where their market power is relatively similar, the market in question is an oligopoly. On the other hand, if a single entity operates in the market, that market is a monopoly.

Often, information is incomplete with regards to the players and their share in a given market. Hence, the research question to be answered is how to estimate the degree of market concentration using mathematical tools, where the market shares are not known for all companies which are active in that market.

This study was structured as follows. Firstly, the concepts of market share and the degree of concentration are described along with the main mathematical indicators used to compute the degree of market concentration. An algorithm to estimate the Herfindahl–Hirschman Index (HHI) and its application to the biomass sector of Romania is then presented in the last part of this paper.

1.1. Market Share Approach

The typical approach by competing authorities around the world is to first define the relevant market and then to assess the market power of companies in that market [24]. Secondly, the analysis is then focused on the market share. This is based on the fact that a monopoly, which has a 100% market share, has a high market power, whereas a company with a very small market share does not have the capability to artificially inflate the market and therefore, has no market power [25].

It should be kept in mind that the above depiction is generally valid and that there are exceptions where a monopolist has less market power than an enterprise in an oligopolistic market (as a result of sectoral regulations, lack of barriers to entry in the market, etc.) [26]. In addition, the concept of market power is not synonymous with market share. For example, a company with a small market share that controls the inputs needed by other market agents (with large upstream market shares) is able to influence the market and therefore has market power (even if this is not apparent from a market share analysis) [27].

However, there is a strong and positive relationship between the market power and the market share of a company. Market shares and concentration levels provide the first useful clues of the market structure, which relates to relevant economic concentrations, as well as for the competitors to the parties engaged in an economic concentration [28,29]. Market shares are generally calculated on the basis of the annual sales values/sales data. However, if the analyzed market is characterized by very homogeneous products (a cheaper product can successfully duplicate a more expensive product), then it is recommended to calculate the market shares based on the sales volumes and not on the sales values [30–32].

1.2. Indicators of Degree of Market Concentration

The level of market concentration provides useful information in analyzing the degree of competition in that market. There are several market concentration indicators, where each of them starts with the calculation of the market share [33,34]. Generally, the indicators are calculated based on the value of the products/services traded, but they can also be calculated on the basis of the volume of products/services traded (depending on the market specificity). The main indicators of market concentration include the concentration ratio (CR) [35] and the Herfindahl–Hirschman index (HHI) [36].

The concentration ratio is the sum of the market shares of the largest players in the market. Generally speaking, a small number of businesses is indicative of an oligopolistic nature of a market (i.e., a small number of enterprises control a significant part of the market). The ratio's value varies between 0 (perfect competition) and 100 (oligopoly if the number of companies 'n' > 1 and monopoly if $n = 1$). The market share of the ith undertaking is calculated using the symbol Si. The concentration rate is calculated using the following formula:

$$\mathrm{CR}_k = \sum_{i=1}^{k} S_i \tag{1}$$

where S_i is the market share of the enterprise in that sector and k represents the top k companies of the market, ranked by their market shares. The value of top firms or top 'k' firms may be three or maximum eight. The most commonly used values for 'k' are four and eight. If the top firms keep on gaining market share, then we say that the industry has become highly concentrated.

The HHI is the sum of the squares of the market shares of the all companies based in that market. Therefore, it attaches greater importance to enterprises with a larger market share. The HHI is calculated by summing the squares of the market shares of all companies that are active in the market. This index can be calculated according to the following formula:

$$\mathrm{HHI} = \sum_{i=1}^{n} S_i^2 \tag{2}$$

where S_i is the market share of the firm "i" and "n" represents the number of enterprises operating in that market.

The HHI is the most used indicator of market concentration by competition authorities. Its value varies between 0 (perfect competition) and 10,000 (monopoly).

The levels of market concentration fall into the following categories: weakly concentrated market, concentrated market, highly concentrated market. The levels adopted by the European Commission and the Department of Justice-federal trade Commission (DOJ-FTC), respectively, were used. In Table 1, we could see the concentration degree limits of the HHI.

Table 1. Concentration degree limits of the Herfindahl–Hirschman index (HHI).

Concentration Degree	HHI	
	European Commission	**Department of Justice**
Low	[0–1000]	[0–1500]
Medium	[1000–2000]	[1500–2500]
High	[2000–10,000]	[2500–10,000]

Source: Calkins [37].

An algorithm for calculating the upper and lower limits of the HHI is described in Wichmann et al. [38]. The authors' idea is based on the fact that, due to insufficient data held by a competition authority, the exact value of the HHI cannot be calculated. Such a situation prevails where a large number of businesses operate in a market and the competition authority only "knows" the market shares of the largest companies. However, if the goal is to fit an entity into one of the HHI index ranges [0–1000], [1000–2000] or [2000–10,000], in some cases, it may be possible to characterize the market in terms of degree of concentration, based on the shares of the largest companies operating in that market. A similar approach was developed by Naldi and Flamini [39]. The study presents an interval estimation of the HHI, when the information about the market is incomplete and only the largest market shares are known. The algorithm proposed by the authors is based on giving a closer upper limit for the HHI when the residual value is greater than the market share of the smallest known undertaking. Other economists utilized techniques from combinatorics to derive a closed form solution for an estimator of that portion of the Hirschman–Herfindahl index, which measures the concentration for the segment of the market with an unattributed market share. Hence, in a study based on 1684 banking markets during 1990–1992 [40], the authors indicate that the HHI, market share inequality, and the importance of major firms are positively related and the number of firms is negatively related to profit rates. Nauenberg et al. [41] estimated deposit-rate and loan-rate equations in which the HHI is decomposed into components that reflect share inequality and number of competitors and, alternatively, by adding measures of share inequality and the number of competitors as additional explanatory variables. Hannan [42] derived a closed form solution for an estimator of that portion of HHI that measures concentration for that segment of the market with unattributed market share. The index makes more complete use of sample information than other more conventional measures of limited-information market concentration, such the CR_4 and CR_8 indices.

2. Materials and Methods

In some markets, there is a large number of active businesses. Thus, it is almost impossible to compute the exact degree of market concentration by accurately calculating the Herfindahl–Hirschman Index. Instead, a lower and an upper limit of this index was calculated to achieve an appropriate estimate of the concentration on this market.

Consider a market with a finite number of operating firms, on which only the market shares of the top k companies are known, ordered in descending order. Thus, the following relationship can be found:

$$S_1 \geq S_2 \geq \ldots \geq S_k \geq S_{k+1} \ldots \geq S_n \tag{3}$$

where the market shares $S_1, S_2, \ldots S_k$ are known, but $S_{k+1}, S_{k+2}, \ldots S_n$ are unknown and the following expression for HHI can be found:

$$\text{HHI} = S_1^2 + \ldots + S_k^2 + S_{k+1}^2 + \ldots . + S_n^2 \tag{4}$$

Furthermore, it was attempted to find the two limits (upper and lower) M and N, such that:

$$N \leq \text{HHI} \leq M \tag{5}$$

2.1. *Computing an Upper Limit M for HHI*

Given the fact that:

$$S_1 \geq S_2 \geq \ldots \geq S_k \geq S_{k+1} \ldots \geq S_n,\ S_1 + S_2 + \ldots + S_n = 100 \tag{6}$$

Yields the inequalities:

$$S_{k+1}^2 + \ldots . + S_n^2 \leq S_{k+1} \times S_k + \ldots . + S_n \times S_k \tag{7}$$

$$S_{k+1}^2 + \ldots. + S_n^2 \leq (S_{k+1} + S_{k+2} + \ldots S_n) \times S_k \tag{8}$$

$$S_{k+1}^2 + \ldots. + S_n^2 \leq [100 - (S_1 + S_2 + \ldots + S_k)] \times S_k \tag{9}$$

Hence, using Formula (4), one obtains:

$$\text{HHI} \leq S_1^2 + \ldots + S_k^2 + (S_{k+1} + S_{k+2} + \ldots S_n) \times S_k \tag{10}$$

Given that n and k are unknown, the result of the upper limit for the HHI is M, where:

$$M = S_1^2 + \ldots + S_k^2 + [100 - (S_1 + S_2 + \ldots + S_k)] \times S_k \tag{11}$$

2.2. Computing a Lower Limit N for HHI

In order to get a lower limit, the mean inequality formulas were used [43,44].

Proposition 1. Cauchy–Schwartz inequality. For any real numbers, $a_1, a_2, \ldots a_n$ and $b_1, b_2, \ldots b_n$, the following inequality holds:

$$\left(\sum_{i=1}^{n} a_i b_i\right)^2 \leq \left(\sum_{i=1}^{n} a_i^2\right)\left(\sum_{i=1}^{n} b_i^2\right) \tag{12}$$

with equality when the two sequences are proportional, i.e., $\frac{a_i}{b_i} = k$, where k is constant.

The proof of the inequality is in Appendix B.

Proposition 2. The root mean square is greater or equal to the arithmetic mean for n positive real numbers.

$$\frac{S_1 + S_2 + \ldots S_n}{n} \leq \sqrt{\frac{S_1^2 + S_2^2 + \ldots + S_n^2}{n}} \tag{13}$$

The proof of the inequality is in Appendix C.

Then, we applied the above inequality for the values $S_{k+1}, S_{k+2}, \ldots S_n$, to obtain:

$$\text{HHI} = S_1^2 + \ldots + S_k^2 + S_{k+1}^2 + \ldots. + S_n^2 \geq S_1^2 + \ldots + S_k^2 + \frac{(S_{k+1} + \ldots + S_n)^2}{n-k} \tag{14}$$

Given that n and k are known, it was obtained a lower limit for HHI as N, where:

$$N = S_1^2 + \ldots + S_k^2 + \frac{(S_{k+1} + \ldots + S_n)^2}{n-k} \tag{15}$$

$$N = S_1^2 + \ldots + S_k^2 + \frac{[100 - (S_1 + \ldots + S_k)]^2}{n-k} \tag{16}$$

3. Results and Discussion

Table A1 from Appendix A shows the main biomass producers from Romania in 2018 and their market shares. Unfortunately, out of the 28 biomass producers, only the market shares of the top 12 companies were known.

The algorithm described earlier was used to estimate the HHI index. The upper limit (M) and the lower limit (N) were calculated using the Equations (12) and (A2). In this case, we had n = 28 and k = 12.

M was calculated as follows:

$$\begin{gathered} M = S_1^2 + \ldots + S_{12}^2 + [100 - (S_1 + S_2 + \ldots + S_{12})] \times S_{12} \\ M = (16.2)^2 + (12.7)^2 + (11.3)^2 \ldots + (0.8)^2 + [100 - (16.2 + 12.7 + \ldots + 0.8)] \times 0.8 \\ M = 886.76 + [100 - (88.4)] \times 0.8 \\ M = 896.04 \end{gathered} \tag{17}$$

N was calculated as follows:

$$N = S_1^2 + \ldots + S_k^2 + \frac{[100-(S_1+\ldots+S_k)]^2}{n-k}$$
$$N = 886.76 + \frac{[100-(88.4)]^2}{28-12} \tag{18}$$
$$N = 895.17$$

Hence, the range of HHI is:

$$895.17 \leq \text{HHI} \leq 896.04 \tag{19}$$

Therefore, according to the limit values for the HHI in Table 1, the biomass sector of Romania has a low degree of market concentration.

4. Conclusions

According to the algorithm presented here, although there are not many entities that are active in the biomass sector in Romania, where their market share is known, it is possible to estimate the concentration degree and it was found to be very low. From Table A1 of Appendix A, it can be seen that the top 3 and top 5 companies in the sector (CR_3 = 40.2% and CR_5 = 56.8%) do not have an aggregated market share of more than 60%, which confirms that the market had a low concentration. These results are also in line with other studies on the biomass sector at the EU level [43–45].

The low level of market concentration is generally correlated with a high level of competition. However, as mentioned above, the market share of the operators is not the only determinant of the market structure. In particular, the distribution channels adopted may have a significant effect, such that the operators' reliance on direct sales and affiliated agents may reduce the competitive power.

However, an increase in the degree of concentration is not necessarily a bad thing. Firstly, if businesses grow in size, it may be able to benefit from economies of scale, thereby obtaining lower cost averages. This is likely to occur in fixed-cost industries and specialized opportunities [46,47].

One of the fundamental objectives pursued by the Treaty on the Functioning of the European Union was to maintain and stimulate a competitive environment, conducive to innovation, in support of the final consumer. Therefore, the regulators' task is to work closely with the competent institutions in the area of market competition in support of competitive market development. Such actions are necessary to open up the market to potential competitors.

In this paper, it is assumed that the number of players on a market is known, but the market share is known only for some of them. This is not an impossible assumption as, for some markets (i.e., regulated markets), the number of firms active on the market is well known, and there is an estimation of the total value of the services/products traded in that market but the turnover is known only for some firms (generally, the largest of these). Last but not least, it must be considered that the methodology described in the paper could be extended for other situations when it is difficult to find out all the information required for the computation of HHI.

The main limitation of estimating the HHI is that it is hard to compute the market shares of some markets, as the total turnover of the sector is not easy to find. Another limitation arises in markets that have several participants either entering or exiting the market.

Further research should focus on refining the method used to estimate the HHI and to apply this method to other interesting energy sectors related to renewable energy: hydro, geothermal and wind.

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Appendix A

Table A1. Biomass main producers in Romania at the 2018 level.

Biomass Producer	Market Share
ALUCO	16.2%
ARIADNE IMPEX	12.7%
BIOMASS ENERGY FARMING	11.3%
BIOSAL ENERG	8.4%
ELECTRAWINDS-R SRL	8.2%
ERPEK IND SRL	7.9%
EXPLOCOM GK	7.2%
GYPPA SRL	6.8%
KONTRASTWEGE	5.4%
MAYO BIOENERGY	2.5%
SALICANTHUS ENERG	1.0%
TREFOREX SA	0.8%

Source: Ministry of finance [48].

Appendix B

Proof of Inequality (12)

Consider two vectors $a = (a_1, a_2, \ldots a_n)$ and $b = (b_1, b_2, \ldots b_n)$. The inner product is defined as: $\langle a, b\rangle = \sum\limits_{i=1}^{n} a_i b_i$, while the norms are given by: $||a|| = \sqrt{\sum\limits_{i=1}^{n} a_i^2}$ and $||b|| = \sqrt{\sum\limits_{i=1}^{n} b_i^2}$.

Hence, the inequality (*) could be rewritten as:

$$\langle a, b\rangle \le ||a|| \times ||b|| \tag{A1}$$

Let $\lambda \in R$, given by $\lambda = \langle a, b\rangle / ||b||^2$.

Then, the equation becomes:

$$\begin{gathered} 0 \le ||a - \lambda b||^2 \\ = \langle a, a\rangle - \langle \lambda \times b, a\rangle - \langle a, \lambda \times b\rangle + \langle \lambda \times b, \lambda \times b\rangle \\ = \langle a, a\rangle - \lambda \times \langle b, a\rangle - \lambda \times \langle a, b\rangle + \lambda^2 \times \langle b, b\rangle \\ = \langle a, a\rangle - \frac{\langle a,b\rangle}{||b||^2} \times \langle b, a\rangle - \frac{\langle a,b\rangle}{||b||^2} \times \langle a, b\rangle + \left(\frac{\langle a,b\rangle}{||b||^2}\right)^2 \times \langle b, b\rangle \\ = \langle a, a\rangle - \frac{(\langle a,b\rangle)^2}{||b||^2} - \frac{(\langle a,b\rangle)^2}{||b||^2} + \left(\frac{\langle a,b\rangle}{||b||^2}\right)^2 \times ||b||^2 \\ = ||a||^2 - \left(\frac{\langle a,b\rangle}{||b||^2}\right)^2 \end{gathered} \tag{A2}$$

Therefore, $0 \le ||a||^2 - \left(\frac{\langle a,b\rangle}{||b||^2}\right)^2$, or $\langle a, b\rangle \le ||a|| \times ||b||$, which proves the inequality.

Appendix C

Proof of Inequality (13)

The above inequality was a direct consequence of the Cauchy–Schwarz inequality. In Inequality (13), we took $a_1 = S_1, a_2 = S_2, \ldots, a_n = S_n$, $b_1 = b_2 = \ldots = b_n = 1$ and obtained:

$$\left(S_1^2 + S_2^2 + \ldots + S_n^2\right)(1 + 1 + \ldots + 1) \ge (S_1 + S_2 + \ldots S_n)^2 \tag{A3}$$

By dividing both sides by n^2 and then taking the square root on both sides of the inequality, we obtain:

$$\sqrt{\frac{S_1^2 + S_2^2 + \ldots + S_n^2}{n}} \geq \frac{S_1 + S_2 + \ldots S_n}{n} \tag{A4}$$

which proves Inequality (13).

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