COMPUTER RESEARCH AND MODELING
2023 VOL. 15 NO. 1 P. 129–140
DOI: 10.20537/2076-7633-2023-15-1-129-140

КиМ

ENGINEERING AND TELECOMMUNICATIONS

UDC: 519.8

Approach to Estimating the Dynamics of the Industry Consolidation Level

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Received 01.11.22.
Accepted for publication 23.12.2022.

In this article we propose a new approach to the analysis of econometric industry parameters for the industry consolidation level. The research is based on the simple industry automatic control model. The state of the industry is measured by quarterly obtained econometric parameters from each industry's company provided by the tax control regulator. An approach to analysis of the industry, which does not provide for tracking the economy of each company, but explores the parameters of the set of all companies as a whole, is proposed. Quarterly obtained econometric parameters from each industry's company are Income, Quantity of employers, Taxes, and Income from Software Licenses. The ABC analysis method was modified by ABCD analysis (D — companies with zero-level impact to industry metrics) and used to make the results obtained for different indicators comparable. Pareto charts were formed for the set of econometric indicators.

To estimate the industry monopolization, the Herfindahl – Hirschman index was calculated for the most sensitive companies metrics. Using the HHI approach, it was proved that COVID-19 does not lead to changes in the monopolization of the Russian IT industry.

As the most visually obvious approach to the industry visualization, scattering diagrams in combination with the Pareto graph colors were proposed. The affect of the accreditation procedure is clearly observed by scattering diagram in combination with red/black dots for accredited and nonaccredited companies respectively.

The last reported result is the proposal to use the Licenses End-to-End Product Identification as the market structure control instrument. It is the basis to avoid the multiple accounting of the licenses reselling within the chain of software distribution.

The results of research could be the basis for future IT industry analysis and simulation on the agent based approach.

Keywords: Herfindahl – Hirschman index, ABCD analysis, monopolization of IT industry

Citation: *Computer Research and Modeling*, 2023, vol. 15, no. 1, pp. 129–140.

КОМПЬЮТЕРНЫЕ ИССЛЕДОВАНИЯ
И МОДЕЛИРОВАНИЕ 2023 Т. 15 № 1 С. 129–140
DOI: 10.20537/2076-7633-2023-15-1-129-140

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ИНЖИНИРИНГ И ТЕЛЕКОММУНИКАЦИИ

УДК: 519.8

Подход к оценке динамики уровня консолидированности отрасли

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Получено 01.11.22.
Принято к публикации 23.12.2022.

В данной статье нами предложен новый подход к анализу эконометрических параметров отрасли для уровня консолидированности отрасли. Исследование базируется на простой модели управления отраслью в соответствии с моделью из теории автоматического управления. Состояние отрасли оценивается на основе ежеквартальных эконометрических параметров получаемых в обезличенном виде от каждой компании отрасли через налогового регулятора.

Предложен подход к анализу отрасли, который не предусматривает отслеживания эконометрических показателей каждой компании, но рассматривает параметры всех компаний отрасли, как единого объекта.

Ежеквартальными эконометрическими параметрами для каждой компании отрасли являются доход, количество работников, налоги и сборы, уплачиваемые в бюджет, доход от продажи лицензионных прав на программное обеспечение.

Был использован ABC-метод анализа модифицированный до ABCD-метода (D — компании с нулевым вкладом в соответствующую отраслевую метрику) для различных отраслевых метрик. Были построены Парето-кривые для множества эконометрических параметров отрасли.

Для оценки степени монополизированности отрасли был рассчитан индекс Херфиндаля – Хиршмана (ИХХ) для наиболее чувствительных метрик отрасли. С использованием ИХХ было показано что пандемия COVID-19 не привела к существенным изменениям уровня монополизированности российской ИТ-отрасли.

В качестве наиболее наглядного подхода к отображению отрасли было предложено использовать диаграмму рассеяния в сочетании с присвоением компаниям отрасли цвета в соответствии с их позицией на Парето-кривой. Также продемонстрирован эффект влияния процедуры аккредитации путем отображения отрасли в формате диаграммы рассеяния с красно-черным отображением аккредитованных и неаккредитованных компаний, соответственно.

И заключительным результатом, отраженным в статье является предложение использования процедуры сквозной идентификации при организации цепочек поставок программного обеспечения с целью контроля структуры рынка программного обеспечения. Этот подход позволяет избежать множественного учета при продаже лицензий на программное обеспечение в рамках цепочек поставок.

Результаты работы могут быть положены в основу дальнейшего анализа ИТ-отрасли и перехода к агентному моделированию отрасли.

Ключевые слова: индекс Херфиндаля – Хиршмана, ABCD-анализ, монополизированность ИТ-отрасли

Introduction

In this article we propose some approaches to IT industry analysis. Our goal is to define indicators and how to graph them for industry management.

Correlation of industry dynamics and regulation efforts are analyzed on the panel date in 1990–2010 by several scientific teams [Urmanbetova, 2003; Wooldridge, 2010] et al.

We will describe IT industry as a set of Russian companies with some econometric parameters which are determined quarterly. We propose an approach to analysis of the IT industry, which does not provide for tracking the economy of each IT company, but explores the parameters of the set of all IT companies as a whole. Universities, research institutions as well as foreign IT organizations and specialists are above our discussion. Different sources give different data about the total number of IT companies in Russia. This was due to the fact that there was no official list of IT activities until recently. Spark-Interfax gives the number of 73,000 IT companies in September 2022 [Interfax, 2022].

Nearly the same number is given by the Higher School of Economics (HSE) for January 2021 [HSE, 2022]. The Russian Federal Statistic Service estimates that the total income of about 100 000 Russian information and communication companies is 4,733 billion rubles in 2020.

The data set we have used includes metrics from about 40,000 anonymized business entities from IT industry.

This data is sufficient for calculations and plotting, however, the results obtained may differ from the real data for the industry.

The total number of IT industry companies does not exceed 100,000. So we can work with the data set without any restrictions from computer productivity and memory in use.

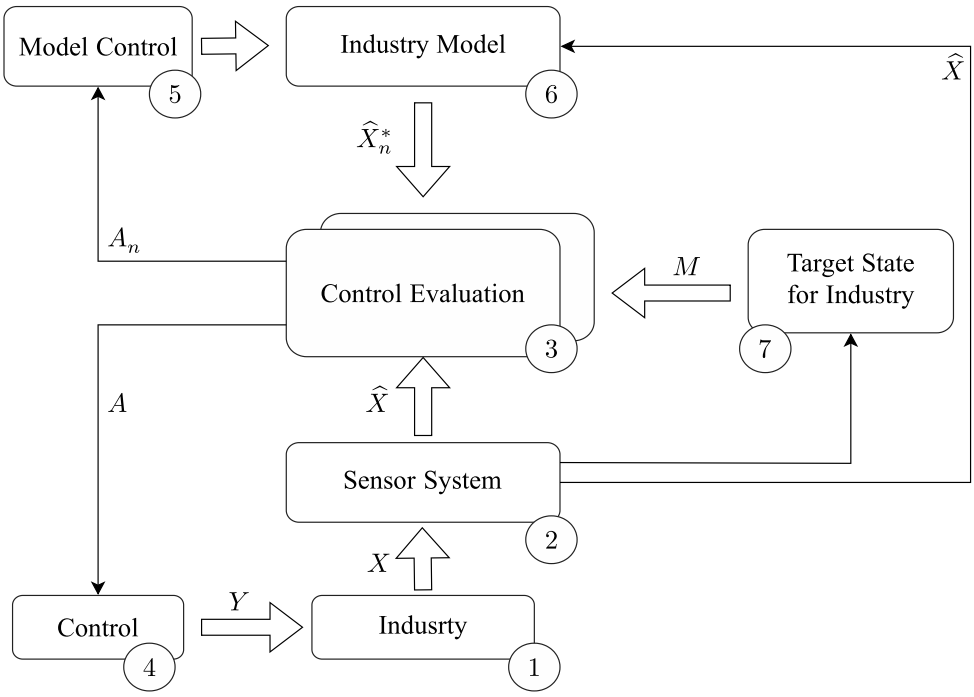

Figure 1. Simple model of industry control

We will use the simple approach to the industry control model. It is presented in Fig. 1.

Here we use two-level control with simulation as an industry dynamics prediction approach.

Sensor System 2 measures the X vector with all econometric parameters for each company from Industry 1.

Results of measurements $\widehat{X}$ are used by management system 3 to determine the impact parameters both for Industry Model 6 and real Industry 1. Control 4 and Model Control 5 are used for impact on Industry 1 and Industry Model 6.

For the Industry Model there is no need in the Sensor System — we get the $\widehat{X}_n^*$.

The target of Industry Control M is adaptively defined by 7. The nature of M is the result of human-managed goal setting.

One of the most popular goals of industry control is monopolization prevention within the total industry parameters growth.

In our research we also propose the data scattering diagram for visual estimation of the regulatory impact result of IT companies accreditation procedure.

State-of-the-art

The problem of market share and prediction of industry impact results is not new.

ABC analysis is a well-established categorization technique based on the Pareto Principle for determining which items should get priority in the management of a company's inventory [Pareto, 1971].

In [Ravinder, Misra, 2016] in discussing this topic, today's operations management and supply chain textbooks focus on dollar volume as the sole criterion for performing the categorization. A large body of research was summarized based on multiple criteria ABC analysis that has accumulated since the 1980s and recommend that textbooks incorporate their key findings and methods into their discussions of this topic.

In our research we used the ABC analysis for market share of IT companies for Income, Taxes and Employee number for 2019–2020.

The Herfindahl index (also known as Herfindahl – Hirschman Index, HHI, or sometimes HHI-score) is a measure of the size of firms in relation to the industry they are in and is an indicator of the amount of competition among them [Rhoades, 1993; Hirschman, 1964].

Named after economists Orris C. Herfindahl and Albert O. Hirschman, it is an economic concept widely applied in competition law, antitrust and also technology management.

In 1945 Albert O. Hirschman proposed the equation [Hirschman, 1945]

$$HI = \sqrt{S_1^2 + S_2^2 + \ldots + S_n^2}. \tag{1}$$

The actual equation was proposed by Orris C. Herfindahl in 1950 [Herfindahl, 1950]

$$HHI = S_1^2 + S_2^2 + \ldots + S_n^2, \tag{2}$$

where S_i is the market share of firm i in the market, and N is the number of firms.

The HHI takes into account the relative size distribution of the firms in a market. It approaches zero when a market is occupied by a large number of firms of relatively equal size and reaches its maximum of 10,000 points when a market is controlled by a single firm. The HHI increases both as the number of firms in the market decreases and as the disparity in size between those firms increases.

The US federal agencies generally consider markets in which the HHI is between 1,500 and 2,500 points to be moderately concentrated, and consider markets in which the HHI is in excess of 2,500 points to be highly concentrated. (See U.S. Department of Justice & FTC, Horizontal Merger Guidelines par. 5.3, 2010, https://www.justice.gov/atr/horizontal-merger-guidelines-08192010.) Transactions that increase the HHI by more than 200 points in highly concentrated markets are presumed likely to enhance the market power under the Horizontal Merger Guidelines issued by the Department of Justice and the Federal Trade Commission.

The works of M. Naldi and M. Flamini [Naldi, Flamini, 2014; Naldi, Flamini, 2018] present the results of interval estimation of the Herfindahl – Hirschman index under incomplete market information and of the dynamics of the Hirschman – Herfindahl index under new market entries.

The paper [Sleuwaegen, Dehandschutter, 1986] shows that in addition to theoretical relevance of choice between the Hirschman – Herfindahl index and the concentration ratio, both measures may provide empirically very different information to assess industry performance. It is shown that the correspondence between the two measures can be represented by a horn-shaped figure. The implications of this horn-shaped relationship are investigated in the context of specifying empirical profitability-concentration models. Among different specification effects tested, it is shown that the neglect of the horn relationship may bias the results towards the identification of a critical concentration ratio.

We don't consider the concentration ratio here, but plan to do so later.

IT industry metrics analysis

The ABCD analysis

For market share we use the above mentioned ABC approach. To take into the account companies with zero level participation we add the D group for companies with zero level share in total metrics value.

Results of ABCD analysis for the most popular metrics are presented in Table 1.

Table 1. ABCD metrics for IT industry (2Q2020)

Metrics	All companies			
	A	B	C	D
Income	1792	5815	22,282	4882
Income from licenses	173	300	1257	33,041
Taxes	1250	4210	28,693	618
Employees	3626	7776	20,436	2933

The total number of companies within the IT market in this Pareto diagram is about $N = 40{,}000$. The ABCD graph for industry's companies quarter income 2020Q3 is presented in Fig. 2.

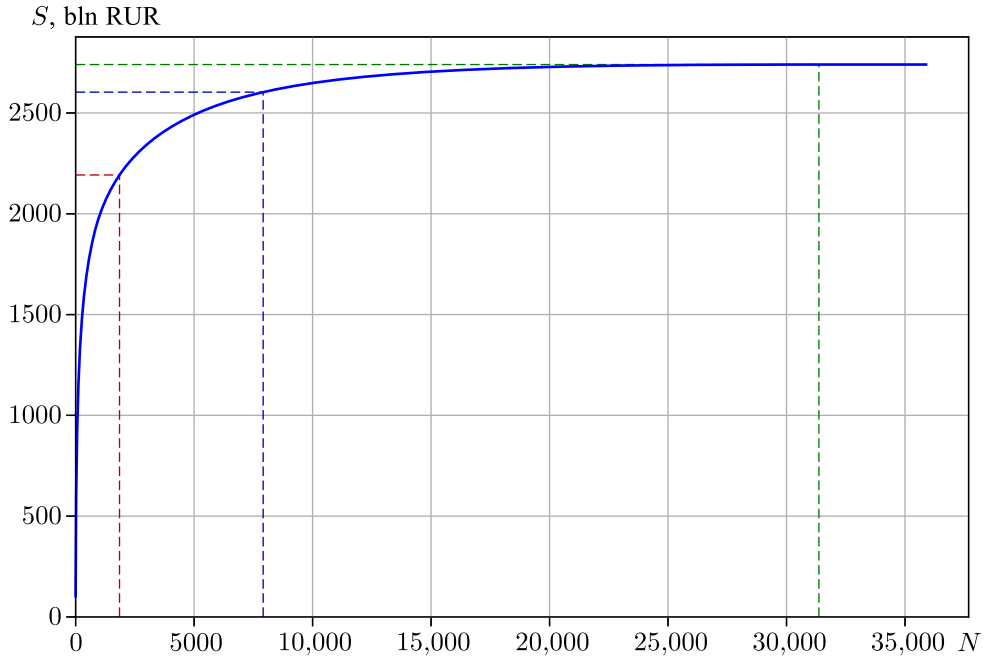

Figure 2. ABCD graph for Income in 2020Q3

One can see that less than 2000 companies are in group A for income and taxes. It means that less than 5 % of IT companies give 80 % of the industry income and taxes.

Scattering Diagram for Industry

One of the possible methods for industry analysis is a scattering diagram.

Logarithmic Scattering Diagram for *Income* and *Number of employees* metrics for 2021Q3 is presented in Fig. 3.

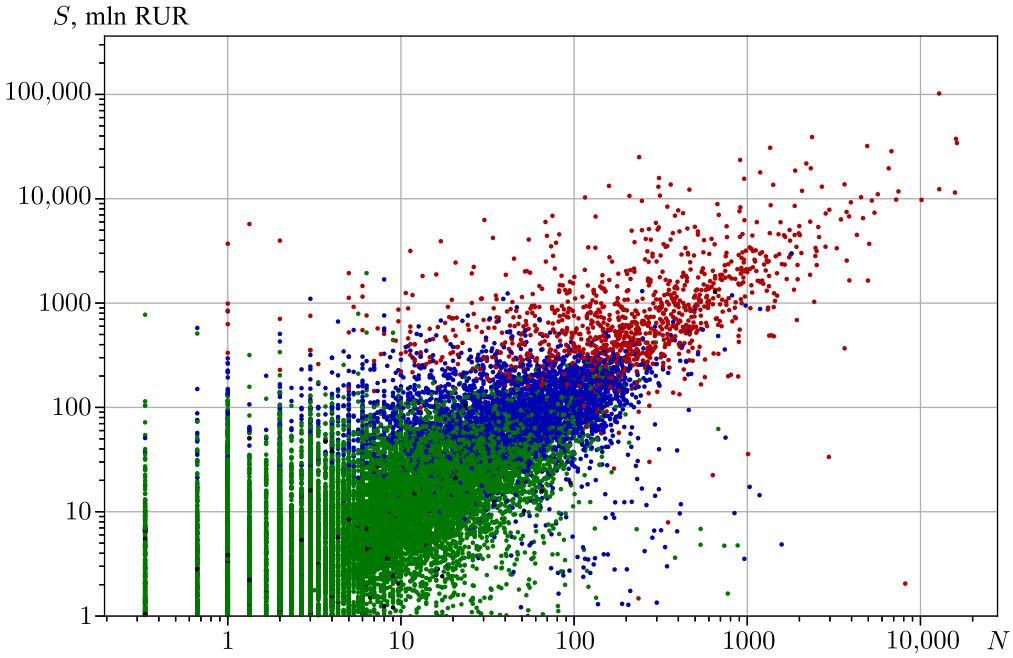

Figure 3. Logarithmic Scatering Diagram for Income and Number of employees metrics for 2021Q3 (the colors correspond to the results of ABCD analysis for paid taxes: red — A, blue — B, green — C and black — D respectively

Colors present the results of ABCD analysis for paid taxes (red — A, blue — B, green — C and black — D, respectively).

The same Logarithmic Diagram is presented in Fig. 4. But here red color is used to denote companies accredited by the Ministry of Digital Development and dark blue is used for others companies.

We can see from Fig. 3 that there is a sharp edge that limits the area of companies from the bottom right. It is due to the fact that the company's staff is limited by the company's income. We can find also a group of companies with staff less than one person and income up to 100 mln RUR. These are two vertical lines on the left side of the diagram. We assume that these companies are affiliated with big companies. The diagram in Fig. 4 shows that big companies are usually accredited, and this is a fully predictable fact.

The diagram in Fig. 5 shows that there is no so strong dependence between "Staff" and "Income from licenses" as compared to "Income". We assume that this fact may be explained was follows. Some of IT companies are "License Wholesalers", so they have relatively large income and small staff.

The diagram in Fig. 6 shows that large companies are usually accredited, just as in Fig. 4.

Scattering Diagrams can be plotted for different metrics and used for different purposes. For example, the activity of companies which go far from the "main companies' area" could be the object for industry regulator's interest.

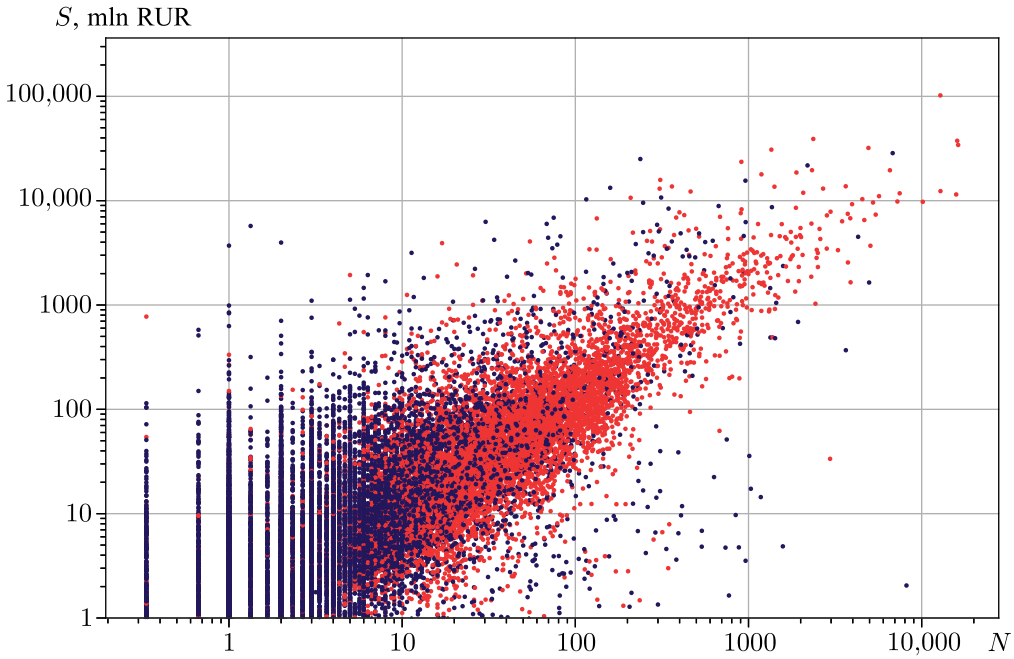

Figure 4. Scattering diagram for Income and Number of employees metrics for 2021Q3 (red is for accredited companies, dark blue is for others)

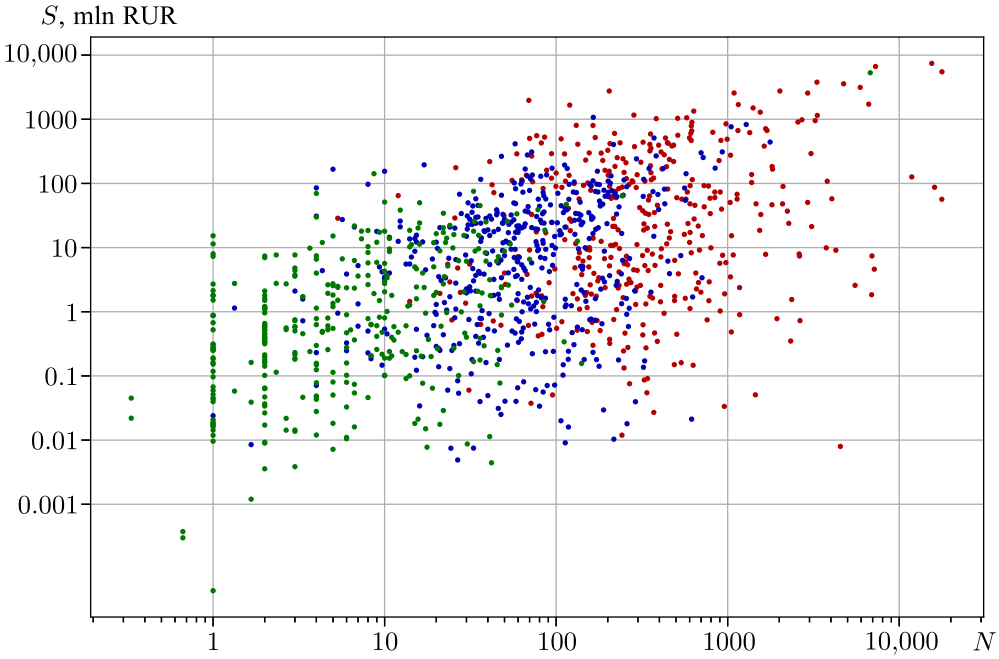

Figure 5. Scattering diagram for Income from Licenses and Number of employees metrics for 2021Q3

Herfindahl – Hirschman Index Evaluation

Combination of ABCD Diagram and Scattering Diagram are useful for the human expert analysis of industry dynamics.

The possible numerical metrics are sizes of A, B, C and D clusters.

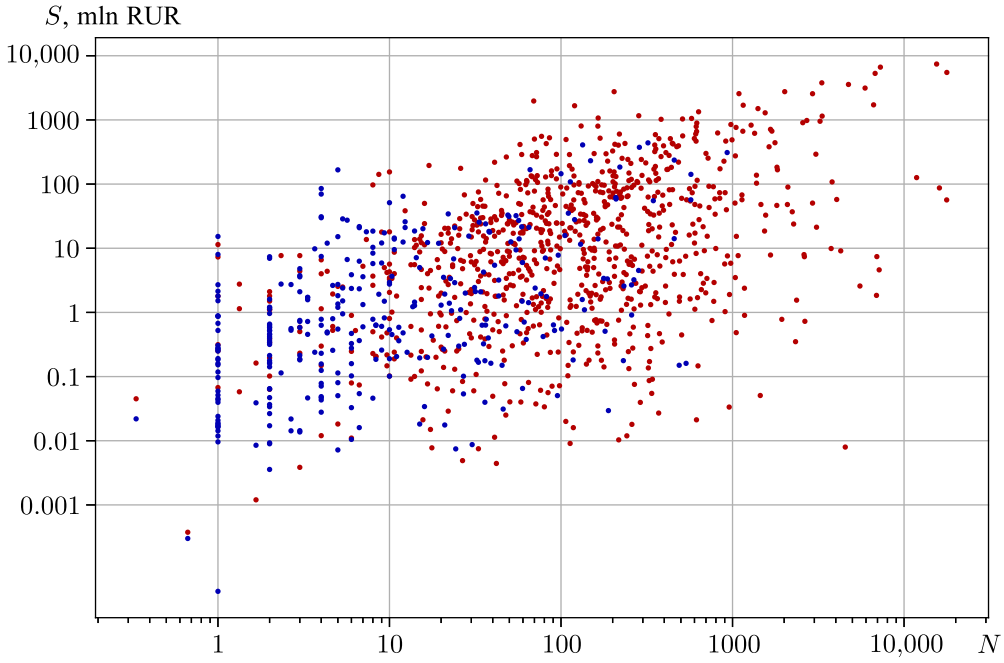

Figure 6. Scattering diagram for Income from Licenses and Number of employees metrics for 2021Q3 (red is for accredited companies, dark blue is for others)

But first we discuss the usability of Herfindahl – Hirschman Index as the industry monopolization metrics.

Income, Income for Licenses are the most obvious metrics for HHI calculation in IT industry. The possible way is also the number of employees, but we suppose it will be a less important parameter.

HHI as a function of time for the whole industry is presented in Fig. 7.

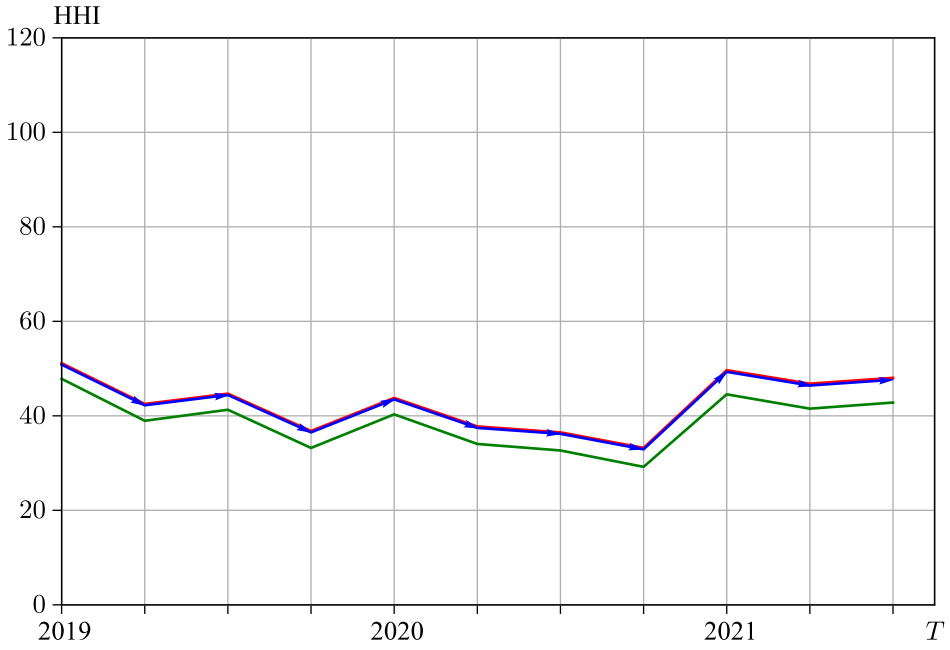

Figure 7. HHI, HHI-50 and HHI-500 industry monopolization indices calculated for “Income” metrics for 2019–2021

For some applications it is a common procedure to use HHI50, which includes only information about 50 biggest companies in the market. For example, this index is used by the Russian Federal Statistics Service. https://rosstat.gov.ru/storage/mediabank/concurent_s.htm

IT industry in Russia is an industry with a relatively large number of companies in several independent clusters.

We also analyze HHI-500 which includes 500 biggest companies in the market.

We clearly understand that the HHI should be calculated with a period of one year to avoid the influence of seasonal fluctuations. But there was a reason to calculate HHI with a period of three months. It gave us a possibility to see the HHI fluctuations within one year period. We used cumulative income data, that is, for example, the designation "income for 2019Q3" corresponds to income for 9 months of 2019, "income for 2020Q4" corresponds to income for the entire 2020.

The general conclusion is based on the statement that any market with an HHI of less than 1,000 is seen as competitive, while one with an HHI of over 1,000 is regarded as being at risk for veering toward a monopoly. So the Russian IT market seems to be concurrent yet.

Results and discussion

We analyzed data and calculated HHI, HHI-50 and HHI-500. The results are given in Table2 and Fig. 7 and Fig. 8.

Table 2. Comparison of the Herfindahl – Hirschman indices of the Russian IT industry monopolization HHI, HHI-50 and HHI-500

Parameter	Income			License trade income		
	HHI-50	HHI-500	HHI	HHI-50	HHI-500	HHI
2019Q1	47.8	50.8	51.1	220.7	225.4	225.5
2019Q2	38.9	42.2	42.5	149.9	155	155.1
2019Q3	41.2	44.4	44.6	145.3	150.3	150.4
2019Q4	33.2	36.5	36.7	601.2	604.1	604.2
2020Q1	40.3	43.4	43.7	128.5	133.9	134
2020Q2	34	37.4	37.7	125.8	131.3	131.4
2020Q3	32.6	36.1	36.5	118.3	123.9	124
2020Q4	29.2	32.9	33.2	100.6	106.3	106.4
2021Q1	44.5	49.3	49.6	252	256.7	256.8
2021Q2	41.5	46.4	46.8	197.3	201.6	201.7
2021Q3	42.8	47.6	48	177.7	183.1	183.2

As we can see, the values of HHI calculated for Income metrics are lower than 60. This means that there is no monopolization of the IT market and the market concentration is relatively low. We can also see from Fig. 7 that the HHI-500 graph line predictably lays between HHI-50 and HHI, and much closer to HHI.

As we can see from Fig. 7, HHI is slightly higher than HHI-50. The difference is less than 10 %. So we can assume that HHI-50 is applicable to markets or industries with a big number of companies and a low concentration ratio, but differs from HHI. It could have importance if the index is used to make decisions for industry support regulation.

HHI calculated for License trade companies is shown in Fig. 8 simultaneously with HHI/HHI50/HHI500 for the *income* metrics. The difference of a few per cent between HHI, HHI-500 and HHI-50 cannot be seen in the graphs due to the scale of the image. We assume that the peak at 2019Q4 can be explained by one or more huge software licenses sales or changing supply chains. HHI for License trade companies is approximately three to five times higher than HHI for IT industry

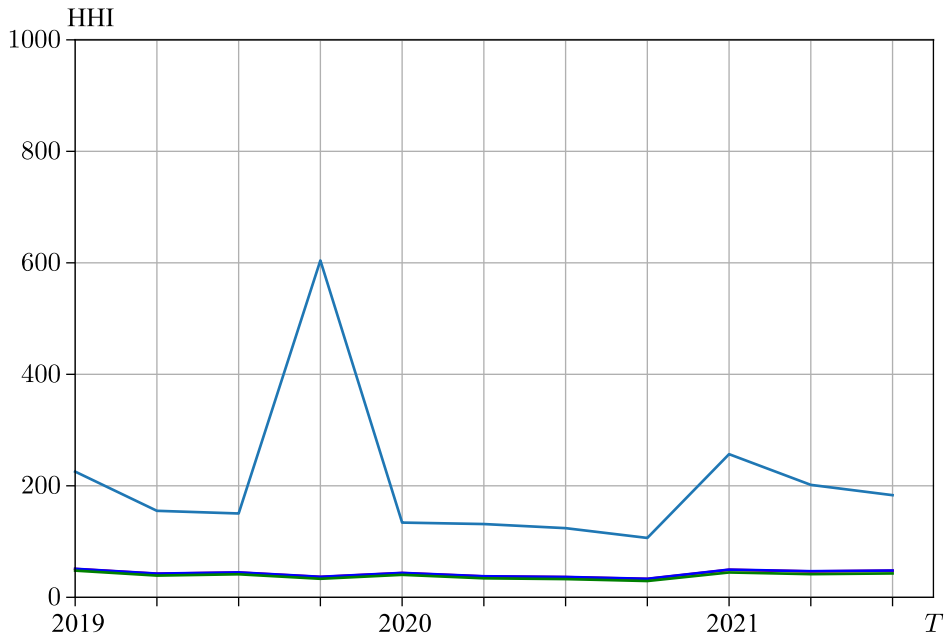

Figure 8. HHI indices for “Income from the sales of licenses” (upper line) and “Income” for 2019–2021

as a whole, as we can easily see from the figures mentioned above *income* 1 and *income from licenses* 2, 3, 4.

We have to take into account the following considerations also. The IT market consists of some kinds of activities which differ from each other and are not always related directly. So it could be more correct to divide IT market (or companies) into groups in accordance with some rules of classification.

At least two documents establishing the rules of classification of activities types of IT companies are known.

One of them is the so-called OKVED, or the All-Russian classifier of types of economic activity. http://www.consultant.ru/document/cons_doc_LAW_163320/

The second one is the Order of the Ministry of Digital Development of Russia dated 08.10.2022 No. 766 “On the list of activities in the field of information technology”.

The comparative analysis of these two documents is far beyond the scope of the article.

HHI for each group of companies in one kind of activities can be much higher than HHI for all IT companies. So we propose to separate some groups of activities closely related with each other and to calculate HHI for such groups of companies separately. Of course, the implementation of such a proposal could require changes in the way information on the activity of IT companies is collected.

It is worth mentioning that such a division of IT companies into groups could be useful not only for analysis of the IT market, or IT industry, but for effective management of IT industry as well.

The first important result is the conclusion that only a small part of IT companies produces a significant part of IT market income.

We assume that, if only licenses were the product of industry, the A cluster within the Pareto ABC diagram would be less than 2000 companies.

If the chain supply effect for licenses trade was taken into account, the net industry income becomes dramatically small.

So it seems to be a good idea to use the regulatory impact for elimination of IT services without IT product. Moreover, we can estimate the consulting revenue connected with each software license if we will use the Licenses End-to-End Product Identification. This service could be provided by some

organizations working with IP in software development or by some distributed ledger (like IPchain.ru). A detailed discussion of this is beyond the scope of this work.

As a result, we have the opportunity to trace the market share for each software including the connected services and hardware facilities.

The HHI graph in time led us to the conclusion that COVID-19 pandemic had no dramatic impact on the Russian IT industry monopolization.

Conclusions

As a result, we propose the new approach to estimating the dynamics of the IT industry consolidation level and IT industry visualization for decision support.

In this article we present:

1. Simple high-level model for the industry control on the basis of the simulation approach.
2. ABCD modification for the ABC approach for IT market share analysis.
3. Scattering logarithmic diagrams as the useful instrument for visual market investigation in combination with Pareto ABCD based coloring of dots corresponding to the IT industry.
4. Herfindahl – Hirschman Index dynamics as a tool for analysis of the industry monopolization. We get a low level of monopolization of Russian IT market on the HHI approach both for income and income from licenses metrics.
5. Proposal to use the Licenses End-to-End Product Identification as the market structure control instrument.

References

Digital Economy Indicators: 2022. — [Electronic resource]. — Available at: https://issek.hse.ru/news/780811313.html (accessed: October 15, 2022).

IT sector in Russia: resilience to new challenges. — [Electronic resource]. — Available at: https://spark-interfax.ru/articles/sektor-it-v-rossii-september-2022 (accessed: October 18, 2022).

Herfindahl O. Concentration in the Steel Industry. — Columbia University, 1950. — [Electronic resource]. — Available at: https://books.google.ru/books?id=vsZ4YgEACAAJ (accessed: October 20, 2022).

Hirschman A. O. National Power and the Structure of Foreign Trade. — Ser. Publications of the Bureau of Business and Economic Research. — University of California: University of California Press, 1945. — [Electronic resource]. — Available at: https://books.google.ru/books?id=IqzYoAEACAAJ (accessed: October 30, 2022).

Hirschman A. O. The paternity of an index // The American Economic Review. — 1964. — Vol. 54, No. 5. — P. 761–762. — [Electronic resource]. — Available at: http://www.jstor.org/stable/1818582 (accessed: October 25, 2022).

Naldi M., Flamini M. Dynamics of the Herfindahl – Hirschman index under new market entries // Economic Papers: A journal of applied economics and policy. — 2018. — Vol. 37, No. 3. — P. 344–362. — [Electronic resource]. — Available at: https://onlinelibrary.wiley.com/doi/abs/10.1111/1759-3441.12222 (accessed: November 13, 2022).

Naldi M., Flamini M. Interval estimation of the Herfindahl – Hirschman Index under incomplete market information // 2014 UKSim-AMSS 16th International Conference on Computer Modelling and Simulation, 2014. — P. 318–323.

Pareto V. Manual of political economy (manuale di economia politica) / translated by Ann S. Schwier and Alfred N. Page. — New York: Kelley, 1971 (1906).

Ravinder H., Misra R. ABC Analysis For Inventory Management: Bridging The Gap Between Research And Classroom // American Journal of Business Education (AJBE). — 2016. — Vol. 9. — P. 1.

Rhoades S. A. The Herfindahl – Hirschman index // Federal Reserve Bulletin. — 1993. — P. 188–189.

Sleuwaegen L., Dehandschutter W. The critical choice between the concentration ratio and the h-index in assessing industry performance // Journal of Industrial Economics. — 1986. — Vol. 35. — P. 193–208.

Urmanbetova A. The effects of consolidation of price-cost margins in the pulp and paper industry. — Georgia Institute of Technology, 2003. — P. 10.

Wooldridge J. M. Econometric Analysis of Cross Section and Panel Data. — Second ed. — Cambridge, Massachusetts: The MIT Press, 2010. — P. 02142.