Estimation of Global Public IaaS market concentration by Linda index

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Abstract. Infrastructure as a Service (IaaS) is one of three key cloud market segments, that include also Platform as a Service (PaaS) and Software as a Service (SaaS). Representing less than a third of the entire market, this segment is projected to keep the higher pace of growth over the next few years. But this growth is mainly driven by market leaders - technology companies with a diversified international business, thereby increasing the concentration of the largest players in the market. This article defines the degree of global IaaS market concentration and whether an oligopoly is being formed. The Linda index is utilized for determination of "oligopoly boundary"- number of key market players.

1 Introduction

Infrastructure as a Service is a cloud-based service with which an organization can outsource its data center capabilities to an external cloud service provider receiving from the latter basic infrastructural services like computing capacities, storage capacities and network resources. IaaS providers on their side take advantage of scale economies via technologies like virtualization and multi-tenancy. [1]

As economy becomes more cloud-based, IaaS along with other cloud segments become more popular. [2] Small and mid-size companies use it to save on facility and personnel costs [3], whilst large enterprises leverage cloud benefits to implement large scale digital transformation. [4]

However, despite such heterogeneous demand that allows providers to locate in different parts of the price-quality space [5], the IaaS market is growing mainly due to certain group of providers, presented solely by cloud divisions of technology giants like Amazon, Microsoft, Google and Chinese Alibaba and Tencent. In this situation, the probability of an oligopoly increases.

That oligopoly of several companies creates strong incentives for these providers to leverage their IaaS market power to distort competition in the diverse markets that depend on access to IaaS. [6] This could firstly affect PaaS and SaaS segments, as these solutions are vertically integrated (from IaaS to PaaS to SaaS) and each layer includes the services of underlying layers. [1]

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High concentration gives prospects to act anticompetitively to market leaders. Moreover, that could lead to structural problems like ineffective competition, which will stimulate anticompetitive conduct.

The article examines the reasons of domination of several players on the global IaaS market and defines whether some type of oligopoly (or duopoly) is being formed on IaaS market. It is only Public IaaS market being considered, as Private IaaS market size is hard to be measured.

Although IaaS represents a segment of entire cloud market, business models differ among the market segments, especially between IaaS and SaaS. This difference concerns product offering, target audience, profitability and entry barriers, that is reflected more clearly in Table 1.

PaaS segment is historically combined into the one market segment with IaaS, as the PaaS services do not have separate providers. Basically, PaaS products were offered by IaaS providers in order to increase the product portfolio and get higher margins. Despite the fact, in this study IaaS and PaaS segments are considered separately.

Table 1. Comparison of Public Cloud Market segments

Market	IaaS	PaaS	SaaS
Key players	Amazon, Microsoft, Alibaba, Google, Tencent	Amazon Microsoft, Alibaba, Google, IBM	Microsoft, Salesforce, Oracle, SAP, Google
Market concentration. Top-5 players market share	High. 80%	High. 70%	Low. 35%
Product portfolio	Limited	Medium	Wide
Target audience	IT administrators	Software developers	End-users
Gross Margin	50-60%	Average of IaaS & SaaS	80-90%
Entry barriers	High	Medium	Low

As demonstrated in Table 1, SaaS market is a highly competitive market, despite the presence of such giants like Microsoft and Salesforce. Its top-5 players market share is 35% [16]. IaaS and PaaS markets are much more consolidated. Major 5 IaaS players have almost 80% of market with Amazon Web Services (Amazon Cloud subsidiary) market share of more than a third. [17]

To better explain this difference, below is a comparison with SaaS and PaaS segments are provided.

Key factors that affect the difference in market concentration are provided below.

1. Product portfolio

- SaaS companies provides to their customers a wide range of products: CRM, ERP, HRM, content management tools, communication platforms, messengers, etc. Moreover, SaaS services are divided in two streams – horizontal (targeted to a wide audience of business users, regardless of their industry) and vertical (targeted to particular industry). This variety allows new companies to take place on the market, despite the presence of major players. [9]
- PaaS' main product offering is a platform: virtual environment for software development. Platforms provide everything needed to develop new software and include debugging, testing, and deployment tools that allow to distribute software to end users. Key features include software for application development, data management, analytics and artificial intelligence, and middleware for integration and orchestration. [10]

- IaaS product offerings represent basic infrastructural services: virtual servers, storages and network. With the development of cloud economy, these services become a commodity. [11]

2. Target audience

- SaaS products are designed for end-users and do not require IT skills, which obviously affects to their higher adoption.
- PaaS services are generally in demand by software developers, who design applications for end-users. Developers need to code, test and deploy their applications by using platforms with full set of tools needed. As development languages along with developers' goals and objectives differ, platforms vary with their functionalities and toolsets.
- IaaS target audience is IT administrators, that control, manage and deliver pool of IT resources to developers. As IaaS requires extensive expertise on the part of the customer to manage the computing infrastructure, thus stimulating small to medium size enterprises to use infrastructure-ready PaaS and SaaS products.

3. Gross Margins

- Typically, SaaS business model should have a gross margin of about 80-90%, [13, 14] which means low cost of sales even for new companies that have recently entered the market.
- IaaS products have average gross margin in a range between 50-60%. [13, 15]
- PaaS gross margin are estimated as an average between IaaS and SaaS business models.

4. Entry barriers

IaaS market has the highest entry barriers for new players. As being mentioned, IaaS providers are generally large technology companies that benefit economies of scale, making enormous investments in facilities and the equipment, as well as in the technology to increase infrastructure utilization and provide essential cloud characteristics such as high elasticity and scalability. [6]

In addition to datacenter investments, the leveraging of the economies of scale requires innovative virtualization, automation, dynamic scaling, and metering technology, that enable IaaS providers to pool resources to dynamically serve multiple consumers with varying demands for physical and virtual resources. Market leaders also invest their money into research and patent licensing, that let them improve the efficiency.

Moreover, if the new player enters the market, it faces the reputational & security barriers. [6] Market leaders are well-known brands with high brand recognition. These companies have proven that they provide reliability for both their own services and their customer data. And it's not only the brand power that challenges new enterer's expansion: migrating data may be the crucial reason to not change the provider, as most customers face data loss issues and other cyber risks. [18]

All that factors above (commoditized services, low margins and high barriers to enter the market) significantly affect the level of concentration on Public IaaS market, thus incentivizing an oligopoly being formed. In next chapter the level of IaaS market concentration over last years will be estimated.

2 Methods of market concentration measurement

To determine the level of market concentration for major companies, Concentration ratio (CR) can be used. This ratio gained the greatest popularity due to relative simplicity of calculations. In the most common practice this ratio is calculated by summarizing shares of each particular market companies in the total production of the product in the relevant market. For the largest n manufacturers, concentration ratio is calculating as in formula below

$$CR_n = s_1 + s_2 + \cdots + s_n = \sum_{i=1}^{n} s_i \quad (1)$$

where: s_i – is share of the producer (company) *i* in the production of a given product, Q_i – total production of the producer *i* for that product, and $Q = \Sigma Q_i$ – total production of that product in the relevant market.

$$s_i = Q_I / Q \quad (2)$$

Another metric that measures a level of market concentration is a Herfindahl-Hirschman index, which is defined as a sum of squares of the share of all manufacturers.

$$HHI = \sum_{i=1}^{m} (s_i)^2 \quad (3)$$

Herfindahl-Hirschman index varies from 10000 (in the case of monopoly with one player holds 100% market share) to 10000/n, where n is a number of companies in industry. [12]

The usage of Herfindahl-Hirschman index increased in relation with its application in practice of the anti-monopoly legislation, especially in the USA, where it has been legally made an important indicator when assessing the admissibility of mergers and acquisitions:

- at HHI<=1000 (low concentrated markets), mergers and acquisitions are freely allowed
- at 1000<HHI<=1800 (moderately concentrated market), a Department of Justice audit is required;
- at 1800<HHI (a high concentrated market), mergers and acquisitions are not allowed if ΔHHI<=50, and a Department of Justice audit is required if ΔHHI>100

Being a convenient tool for determining the level of market concentration, the Herfindahl-Hirschman index cannot determine the balance of power and the number of leading companies in the market. The Linda index can be utilized for this purpose. It was proposed in 1976 by Remo Linda, Head of the Market Structure Division of EU Commission. [8] This index, as well as the concentration ratio, is calculated only for a few largest companies, so it also does not take into account the situation for the "rest of the market". However, unlike the considered indices of CRn concentrations, it seeks to describe a criterion for evaluating oligopolistic structures that may be present.

$$LI = \frac{1}{n(n-1)} \sum_{i=1}^{n-1} \left(\frac{n-i}{i} \frac{CR_i}{CR_n - CR_i} \right)$$

Where n – number of companies for which index is calculated, CRi – is a cumulative share of n market players, CRi – cumulative share of first i players.

The key feature of Linda index is that it allows to determine a "boundary of oligopoly". Representing initially declining broken curve, it sets the boundary of oligopoly (duopoly or monopoly) for the first i companies, if LI_{i+1} exceeds the value of LI_i.

3 Measurement of market concentration on Global Public IaaS market

As being said before, IaaS market is a highly consolidated market, represented generally by technology giants – Amazon, Microsoft, Alibaba, Google, Tencent, IBM. These companies

leverage enormous resources investing in capital expenditures and research and development required for continuous growth.

In this chapter of the study the level of IaaS market concentration will be measured. In addition, the type of market –duopoly/oligopoly will be determined.

Concentration ratio requires information about number of goods produced by each company and the whole market. However, it seems difficult to calculate total production or consumption of such services as neither cloud vendors nor their customers report such information. Thus, this study uses vendors' revenue instead of production in order to estimate the degree of market concentration.

For this goal Gartner's annual IaaS market size estimations are used. In Gartner's Worldwide IaaS Public Cloud Services Market [17], the company provides information about both the market size (Table 2) and market shares of top-5 vendors (Table 3).

Table 2. Worldwide IaaS Public Cloud Services Market by Gartner

$bn	**2015**	**2016**	**2017**	**2018**	**2019**
Market size	16,8	22,2	24,7	32,4	44,5

Table 3. Market share of top-5 IaaS companies by Gartner

2015		**2016**		**2017**		**2018**		**2019**	
Top-5 companies	**Market share, %**	**Top-5 companies**	**Market share, %**	**Top-5 companies**	**Market share, %**	**Top-5 companies**	**Market share, %**	**Top-5 companies**	**Market share, %**
Amazon	39,8	Amazon	44,20	Amazon	49,40	Amazon	47,90	Amazon	45,00
Microsoft	5,8	Microsoft	7,10	Microsoft	12,70	Microsoft	15,60	Microsoft	17,90
Rackspace	2,7	Alibaba	3,00	Alibaba	5,30	Alibaba	7,70	Alibaba	9,10
Alibaba	1,8	Google	2,30	Google	3,30	Google	4,10	Google	5,30
Google	1,5	Rackspace	2,20	IBM	1,90	Tencent	1,90	Tencent	2,80
Top-5 players Market Share	51,6	Total share	58,8	Total share	72,6	Total share	77,2	Total share	80,1

As can be seen, in the period from 2015 to 2019 a cumulative share of major 5 IaaS providers grew from 51,6% in 2015 to 80% in 2019. In addition, in 2019 Amazon and Microsoft represent more almost two thirds of the market. Taking into account that in this period the IaaS market grew 165,2% [16], the rest of the market grew slower than its leaders, thereby underlying the reasons for further concentration described in previous chapters. This tendency is clearly demonstrated on Fig. 1.

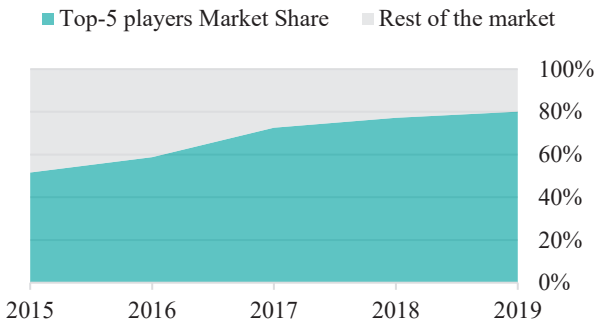

Fig. 1. Market share of top-5 players on IaaS Market, 2015-2019

Application of Herfindahl-Hirschman index to the Gartner's data requires some limitations and assumptions. It applies to the rest of the market – the lack of information about number of all IaaS providers along with their market shares. However, as these shares are less than 1,5-3% in any considered year, the study assumes that they don't add substantial values to the index. The top-5 players HHI on the Fig. 2 shows evolved from moderately concentrated in 2015 to highly concentrated in 2016 – 2019.

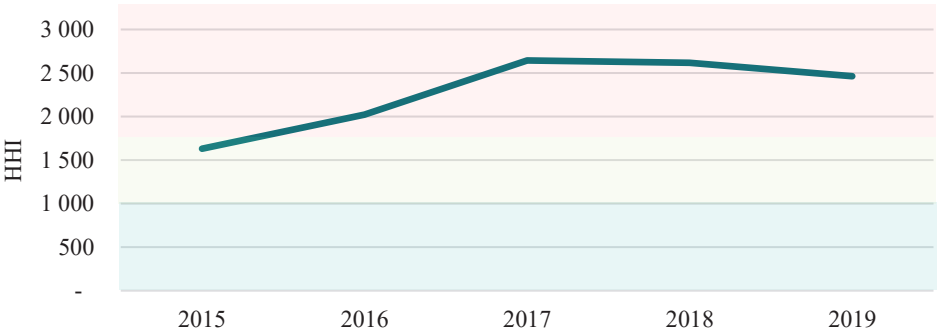

Fig. 2. Top-5 IaaS players Herfindahl-Hirschman Index

The obtained results also support the line that IaaS is a high-concentrated market, even considering the applied assumption of smaller players' insignificant contribution to index values.

However, the results do not give an indication of the balance of power between key players in the market. Thus, the Linda index should be applied to determine the number of major IaaS market providers. Based on the data from Table 3, the Linda indexes for each year were calculated. These results are presented in Figure 3.

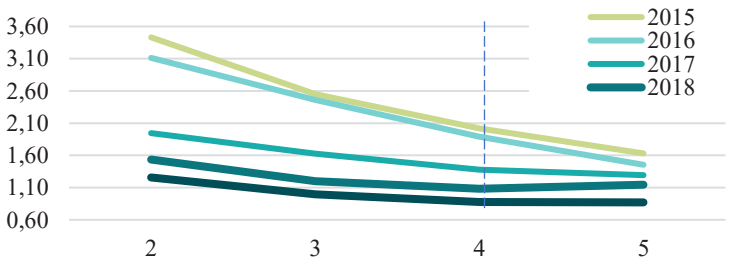

Fig. 3. Linda Ratio for top-5 IaaS providers, 2015-2019

Figure 3 shows that since 2018 there is a noticeable tendency to form an oligopoly of 4 companies (LI_5 tends to be greater than LI_4). That is clearly expressed in 2018, where $LI_5 > LI_4$. Value i=4 means classic or "hard" oligopoly in a competitive environment. That means Global Public IaaS market is forming or has already formed an oligopoly of the 4 largest players: Amazon, Microsoft, Alibaba and Google. In addition, the decline of Linda index for the 1st market player means that it loses its monopolistic position.

Despite the appropriateness of Linda index to the study, there are assumptions that were used to made it. The data used in this study are based on Gartner's estimation of IaaS market and revenue of IaaS providers. As there are no IaaS-only companies in Gartner's researches, IaaS represents a certain portion of their revenue.

Gartner calculations are based on its methodology of IaaS market determination. The company defines IaaS as "standardized, highly automated offering in which computing resources owned by a service provider, complemented by storage and networking capabilities, are offered to customers on demand. Resources are scalable and elastic in near real time and metered by use. Self-service interfaces, including an API and a graphical user interface (GUI), are exposed directly to customers. Resources may be single-tenant or multitenant and are hosted by the service provider or on-premises in a customer's data center." The calculation of the market size and revenue of the 5 largest companies are both based on this methodology.

Furthermore, Gartner data provides information for only first 5 companies, thus the study can't discover an oligopoly of first 5 companies, as Linda index requires data of 6th company's market share for this purpose.

Therefore, there is a need to analyze the sustainability of results obtained with Linda index if the data used deviate. IaaS market size and percentage of IaaS revenue for major players are considered as potentially deviating from their original estimations.

- **Market size estimation.** To assess the impact of IaaS market size on Linda index, the deviation at the level of 15% from the Gartner's estimation is considered.
- **Percentage of IaaS revenue estimation.** As all of major 5 IaaS providers are public companies, we use financial statements, that these companies disclose to calculate a calendar year revenue. For each company we use a revenue of its cloud business department or subsidiary. As fiscal periods vary among these companies (e.g. Alibaba fiscal year ends on March 31 and Microsoft – June 30) we calculate revenues for calendar 2018 and 2019, by summarizing their quarterly earnings ending March 31, June 30, September 30 and December 31. Then obtained revenues are compared with IaaS revenue of these companies, calculated by Gartner. As revenues of cloud business do not consist of only IaaS, IaaS revenue represents certain share of the entire cloud business revenue.

Table 4. AWS share of IaaS Revenue

$ mln	2018	2019
AWS Revenue for	25 655	35 026
Gartner IaaS AWS Revenue	15 495	19 990
as % of AWS Revenue	*60%*	*57,1%*

For example, AWS is historically known as IaaS pioneer, that were specialized on basic cloud infrastructural services and then expanded its cloud portfolio to PaaS and SaaS services. So, the calculated shares of its IaaS business look credible. In further research we will evaluate the sensitivity of "oligopoly boundary" of 4 companies, by changing companies' shares of IaaS revenue at the deviation level of 10%.

- **Revenue of the 6th company.** As Linda index requires to calculate LI_{i+1} to determine the oligopoly boundary of the first i companies, we need to take into account a

market share of the 6th company on the market to determine whether the IaaS oligopoly consists of 5 companies. Thus, we assume the range of revenue starting by revenue of fifth company and twice less. This measure is required only for modeling scenarios of Linda index for 5th company in the rating.

The results of implementing these different scenarios of Linda index to assumptions we described before are as follows.

In 2018, where Linda index curve trend was clearly reversed on 5th company thus determining "oligopoly boundary" of first 4 companies, no significant impact of the above factors on the Linda index was found. That means that the result of 4 companies form an oligopoly is sustainable.

In 2019, where Linda index curve was not reversed explicitly on 5th company and thus meaning absence of the 4 firms oligopoly, there are scenarios when such oligopoly exists. Table 5 shows whether an oligopoly boundary would be found if market size, share of IaaS in Amazon Web Services revenue changed: 4 means there is an oligopoly of 4 firms, 0 means there is no oligopoly. Linda index would determine an oligopoly of 4 companies in scenarios where IaaS market size was bigger for more than 5% and (or) AWS IaaS revenue share was more than 2% lower, than estimated by Gartner.

Table 6 also demonstrates a possibility of an oligopoly of 5 firms would be formed if market share of 6th company would lower than 1,83%.

Table 5. Linda index values by Market size and % of IaaS Revenue of AWS

Amazon		Market Size, $mln (% of deviation)						
		37 788 (-15%)	40 010 (-10%)	42 233 (-5%)	**44 456**	46 679 (+5%)	48 902 (+10%)	51 124 (+15%)
% of IaaS in AWS Revenue	*49%*	4	4	4	4	4	4	4
	50%	4	4	4	4	4	4	4
	52%	4	4	4	4	4	4	4
	54%	0	4	4	4	4	4	4
	55%	0	0	0	4	4	4	4
	57%	0	0	0	0	4	4	4
	59%	0	0	0	0	0	4	4
	60%	0	0	0	0	0	0	4
	62%	0	0	0	0	0	0	0
	64%	0	0	0	0	0	0	0
	66%	0	0	0	0	0	0	0

Table 6. Linda index values by Market size and Market share of 6th company

Amazon		Market Size, $mln						
		37788	40010	42233	**44456**	46679	48902	51124
Market share of 6th company	*2,8%*	0	0	0	0	4	4	4
	2,6%	0	0	0	0	4	4	4
	2,5%	0	0	0	0	4	4	4
	2,3%	0	0	0	0	4	4	4
	2,2%	0	0	0	0	4	4	4
	2,0%	0	0	0	0	4	4	4
	1,9%	0	0	0	0	4	4	4
	1,7%	5	5	5	5	4	4	4
	1,6%	5	5	5	5	4	4	4
	1,4%	5	5	5	5	4	4	4
	1,3%	5	5	5	5	4	4	4

For the rest major players (Microsoft, Alibaba, Google, Tencent) there are opposite results: for each company Linda index would determine an oligopoly of 4 companies in scenarios where IaaS market size was smaller for more than 5% and (or) their IaaS revenue share was more than 2% higher, than estimated by Gartner. (Table 7)

Table 8 shows a possibility of an oligopoly of 5 firms would be formed if market share of 6th company would lower than 1,83%, as it was already demonstrated in Table 6.

Table 7. Linda index values by Market size and % of IaaS Revenue of Microsoft

Microsoft		Market Size, $mln						
		37788	40010	42233	**44456**	46679	48902	51124
% of IaaS in Revenue	17%	0	0	0	0	0	0	0
	18%	4	0	0	0	0	0	0
	19%	4	0	0	0	0	0	0
	19%	4	4	0	0	0	0	0
	20%	4	4	4	0	0	0	0
	20%	4	4	4	0	0	0	0
	21%	4	4	4	4	0	0	0
	22%	4	4	4	4	4	0	0
	22%	4	4	4	4	4	4	0
	23%	2	4	4	4	4	4	0
	23%	2	4	4	4	4	4	4

Table 8. Linda index values by Market size and Market share of 6th company

Microsoft		Market Size, $mln						
		37788	40010	42233	**44456**	46679	48902	51124
Market share of 6th company	2,8%	4	4	4	0	0	0	0
	2,6%	4	4	4	0	0	0	0
	2,5%	4	4	4	0	0	0	0
	2,3%	4	4	4	0	0	0	0
	2,2%	4	4	4	0	0	0	0
	2,0%	4	4	4	0	0	0	0
	1,9%	4	4	4	0	0	0	0
	1,7%	4	4	4	5	5	5	5
	1,6%	4	4	4	5	5	5	5
	1,4%	4	4	4	5	5	5	5
	1,3%	4	4	4	5	5	5	5

Consequently, although the Linda Index does not clearly demonstrate an oligopoly of 4 firms, as it does in 2018, there are many scenarios where small deviations from Gartner's estimates show the existence of such oligopoly. Therefore, global IaaS market can be considered as an oligopoly of 4 firms.

4 Conclusion

The growth of Global Public IaaS market is mostly driven by its leaders – cloud departments of global technology companies, thereby the concentration of the largest players in the market is increasing. The last 5 years the share of 5 major players increased by almost 30 percentage points - from 51,6% in 2015 to 80,1% in 2019. Based on Linda Index, a noticeable tendency to form an oligopoly of 4 companies was defined since 2018. In 2018 Linda Index demonstrated a clear "oligopoly boundary" of 4 companies ($LI_5 > LI_4$). In 2019, despite the absence of an explicit boundary, values of LI_4 and LI_5 were close, which may indicate the stability of that tendency. The sensitivity analysis of the results obtained showed that with

minor changes in the estimates used in the study, the Linda Index would also set an oligopoly boundary of 4 companies in 2019.

5 Prospects for further research

The study conducted above was the first step for further research development. Based on results of concentration degree on Global market, the further works could be focused on regional IaaS markets, that could include countries like USA, China and Russia. Their Cloud markets are generally represented by local players, that could be explained by the requirements of regulators, market attractiveness for foreign providers and other factors. These countries have different level of Cloud adoption thus providing to determine is it possible to prevent an oligopoly or its negative consequences.

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