

Competition Analysis in Cellular Networks: A Colombian Case

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Abstract— Communications through cellular networks like the fifth cellular generation (5G) have become, together with the Internet, the central axis for information exchange. Government agencies seek to control competition, prices, and services provided to people. This is why it is necessary to establish a level of competition between cellular network service providers to regulate mobile services and protect users. In the literature, there is a lack of research in this field, and in Colombia, there is no documentation, only that generated by the regulatory authority, which makes it necessary to research different indexes of market competition to understand the dynamics of mobile services and formulate regulation strategies based on market behavior. This article includes a competition analysis carried out on cellular service providers in Colombia with data from the last 10 years, using the Herfindahl-Hirschman Index (HHI) and Stenbacka to calculate the market indices. The results show that the mobile service market in Colombia has a dominant service provider, a low competitive environment, and is highly concentrated, according to the index values calculated.

Keywords- cellular networks, 5G, competition, mobile services, Stenbacka, HHI.

I. INTRODUCTION

The introduction of the cellular phone and cellular networks has transformed the way we live, offering essential mobile services that we need in the dynamic market of Industry 4.0. Along with technological advances and software development, there is a growing need in the world to regulate the mobile services market. Many technologies are available, but if the country does not have regulations, the service and installation of technology cannot be provided [1].

Regulation is also needed in cellular networks to provide an environment to promote competition in this market. Regulators in each country should adapt regulations to make the market competitive and improve quality, prices, and other metrics for the final user [1].

In this paper, we explore the case for Colombia's market focus in the competition of cellular service providers, to measure the variables that are very important for the country's regulatory entity to make regulatory changes if there exists a monopoly of one service provider, for example [1].

The rest of the paper is structured as follows: In Section II, we present the background. Section III describes the data used and the model to analyze it, along with the indexes used to measure the competition in mobile services in Colombia. The results are presented in Section IV, and finally, we conclude our work in Section V.

II. BACKGROUND

Cellular networks have been developed in the last three decades, and, thanks to the growth of electronics and the Internet, mobile services are part of our lives for work, study, or entertainment. But, as with any service, it must be regulated by the government authorities in each country, generating a market where the service providers and regulators must update their policies and laws to control traffic, prices, and services. It is a challenge to understand market behavior under certain laws or with the entrance of a new service or competitor, even with new virtual service providers [1].

Depending on the type of regulation (no regulation, partial regulation, or full regulation), service providers can assign the service prices and conditions to the users. In any case, a monopoly of some services can be created, where a single operator can manage the market and change it according to its purposes. Competition in this type of market is very hard to achieve. In a market without a monopoly, service providers compete with prices, quality, or other variables, which leads to better service conditions and prices for end users [1].

Telecommunications companies need to offer a large variety of innovative services. The focus of these companies is to keep existing customer loyalty with innovation, prices, and Quality of Service (QoS), and to increase the number of users in a very competitive market, which is the scenario of mobile services. It is recognized that a law generated by the government can encourage competition or limit it. It is important for the regulators to measure the impact of these variables in the mobile service environment in order to make informed adjustments to the regulations [2].

Nowadays, the telecommunication services industry is very dynamic, and, with each new generation or technology, there are new possibilities. At the same time, there is also a need for regulation to control this competition; the service providers strive to provide good quality service while also sustaining their business and their profits. Then, a way to

measure market competition is necessary to establish strategies to control prices, QoS, or to detect a monopoly [3].

The assessment of competition has sparked considerable debate in the economic literature. Traditionally, competition has been gauged through various indicators, including the count of market players, metrics of market concentration like market shares and the HHI, rates of entry and exit, and profitability, among others. Each one of these metrics offers a unique perspective on competition, yet capturing the entirety of this intricate and multi-faceted concept remains challenging [4].

To address the above challenges, some concentration ratios, such as the four-firm concentration ratio (CR4) or the HHI, measure the market share of the largest firms on the market. Higher values indicate lower competition. The H-statistic measures the difference between the observed HHI and the HHI that would result from perfect competition. Higher values suggest lower competition [5].

To measure the competition or dominance in the market, some works directly estimate the concentration ratio in mobile phone markets with the countries' competitiveness indicators or indexes showing the concentration level of a country's mobile telecommunications market and its competitiveness [6][7].

The Global Competitive Index (GCI) is used with the HHI to estimate the competitiveness of mobile telecommunications services in some developed or developing countries, showing the efficiency of the indexes [7]. In [8], Kostić and Živković show the mobile telecommunication networks and services market in the Republic of Serbia and analyze the competition with the HHI as well. A similar analysis was achieved in Morocco [9]. The authors analyze the fixed and mobile markets through the HHI and try to establish the relationship between the regulation and market behavior with the competition levels [9].

In [10], George et al. use the HHI to analyze the competition in Ghanaian telecommunications, showing the difficult task of the regulator in establishing the laws or norms to regulate the mobile market. It needs to be updated; its concentration makes it difficult to compete and give better services to the users.

Aguilar et al. show empirical results for five Latin American countries, analyzing the network effects in the mobile telecommunications market [11]. Their work highlights that, even if there is a dominant service provider present, each country has different behavior and must be analyzed independently, analyzing not only the number of users, but other main variables, like price.

Another index commonly used is Stenbacka, which measures the dominance level of a service provider. The experiment is achieved with two service providers that have a high level of users in the mobile services market. The index has been used by regulators and control entities to study dominance and competition in the telecommunications market [12].

The Stenbacka index has been used to get a dominance measure that classifies when an individual service provider has a dominant position in the market [13]. This

complements the HHI, which measures the concentration of the market [14][15]. Concentration, asymmetry, and dominance characterize the situation regarding the competition in a particular market. Thus, through these values, it can be said how agents interact and analyze the situation of perfect competition and monopoly, and how the market leader is treated [14].

In [17], Ono shows that the competition among the service providers is driven primarily by the size of their installed bases, with moderate influence from indirect network effects. They analyze the dominance in the market, the advantages of each service provider, and the behavior of the users, caused by the competition. The analysis highlights the importance of network effects and the installed base size in platform competition.

Even though there are some indexes used for market competition measures, there are no papers that show an analysis in Colombia. The purpose of this work is to calculate and analyze the results to understand the competition and the behavior over time, identify improvement opportunities, and provide feedback on the results to the service provider authority in Colombia.

In this paper, the open data generated by the government is used, and the HHI and Stenbacka are calculated and analyzed. These indexes are commonly used to measure market competition [6].

III. DATA AND MODEL

To construct our empirical estimations, we use data from a source generated by the Colombian regulator (Comisión de Regulación de Comunicaciones-CRC), for the period 2012–2022: the database of the mobile market in Colombia.

Using the data mining concepts, the model starts defining the process of Knowledge Discovery in Databases (KDD), which starts with the definition of the problem, preparing the data, evaluating models, and finalizing the model, as can be seen in Figure 1 [18].

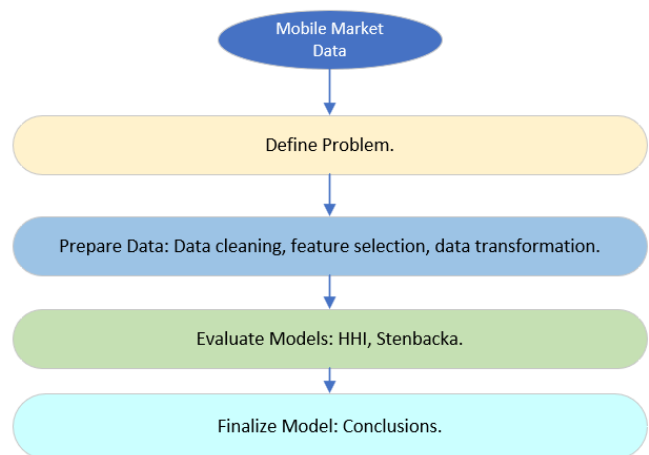


Figure 1. Methodology for data processing and analysis [15].

The objective is to analyze the competitiveness, concentration, and dominance level of mobile service

providers in Colombia, with the available data from 2012-2022.

The main variables found in the preparation of the data are service provider, income, number of users, and traffic.

The data presented by the regulator can be segmented into trimesters, but we work with the monthly data to obtain more samples. Three kinds of data (income, number of users, and traffic) were selected because a good amount of data collected by the regulator is available. Other variables have only a few samples and there were errors in the probability calculation. In addition, we made previous experiments, and the inclusion of some variables like department or cell phone plans in the model had a limited contribution to the algorithms.

The third part of the process is to define the indexes that are going to be used, in this case HHI and Stenbacka Index.

Measuring competition in a market and determining the market power of individual companies is a challenge for economic researchers and authorities. The calculation of concentration measures stands out as a widely used method to evaluate the level of competition within a market [19]. The methods to be used in this paper are HHI and Stenback, which are described below.

A. Herfindahl-Hirschman Index - HHI

The HHI is a widely used coefficient for assessing business concentration, frequently applied to measure the level of concentration within a market. The HHI is calculated as in (1) by summing the squared revenue shares (s) of all service providers (i) in a given market (j) for a specific time (t). The HHI is the sum of the squares of the market percentage of each of the n companies that comprise it, expressed as follows [19]:

$$HHI_{jt} = \sum_{i \in j, t} s_{ijt}^2 \quad (1)$$

The HHI can have values ranging from 0 to 10,000. For example, in the context of horizontal merger guidelines, markets can be categorized with HHIs below 1,500 as unconcentrated, which means high competition. Moderately concentrated markets are in the range of 1,500 to 2,500 HHIs, while HHIs exceeding 2,500 mean high market concentration, which potentially raises significant competitive concerns. These thresholds offer guidance in interpreting HHIs [19].

B. Stenbacka Index

The Melnik, Shy, and Stenbacka index [13] functions as a tool for identifying the values indicative of a company's market dominance through its share. This index is computed based on the variance in market share between the two main entities in the industry, which means the two service providers have more users in the mobile services case. The formula used to calculate is shown in (2) [20]:

$$S^D = \frac{1}{2} [1 - \gamma(S_1^2 - S_2^2)] \quad (2)$$

where S_1 and S_2 are the percentage shares in sales of the first and second mobile service providers with the highest participation, respectively. The competition parameter γ seeks to collect the main aspects of the competition. In the experiments achieved by Stenbacka, this parameter has been probed with three values (1/2, 1 and 2). With a higher value of the parameter, the index will be low, resulting in a high probability of finding dominance in the experiment. In this paper, the parameter value is assumed to be one according to the recommendation of Stenbacka et al. [13]. This index will be an indicator that shows the degree of dominance through the subtraction of one service provider compared to the participation of the largest service provider in the mobile services sector in terms of sales [18]. Low values of the index correspond to minimal barriers to mobile service market entry, indicating that potential competition may constrain the firm's ability to exploit its market power effectively. In contrast, high values of the index signify substantial entry barriers and a reduced expectation of potential competition [18].

IV. RESULTS

In this section, the HHI and Stenbacka indexes are calculated for mobile services data after the data preparation process, which includes data cleaning, feature selection, and data transformation.

The features selected are several accesses, traffic, and incomes, which are the main variables studied and documented by the regulator and have been cleaned and adapted to the research.

A. HHI Results

The HHI is applied by calculating the participation of each mobile service provider in the country. Data from 2012 to 2022 available in postdata [22] is used. This site is created and maintained by the regulator and keeps an updated database of the data reported by the service provider to the regulator agencies.

After the feature selection process, the first variable to be used is the accesses (number of users). The HHI for accesses can be seen in Figure 2.

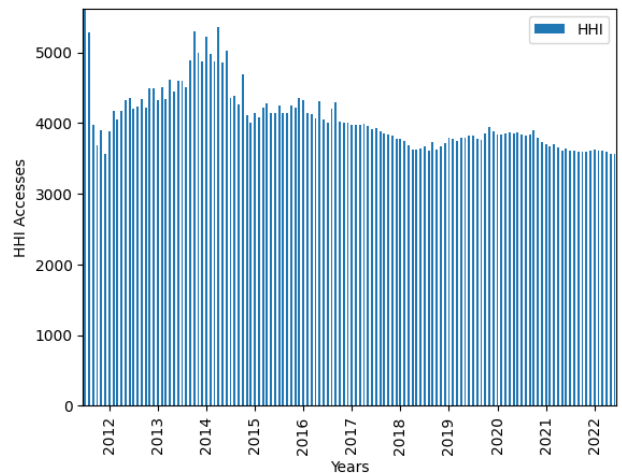


Figure 2. HHI for Mobile Services Accesses in Colombia.

Results show that the index is above 3500, indicating a high concentration of the market and low competition in the accesses variable. The HHI has a decreasing trend.

The second variable to analyze in the same period is the mobile service incomes. The HHI for this can be seen in Figure 3.

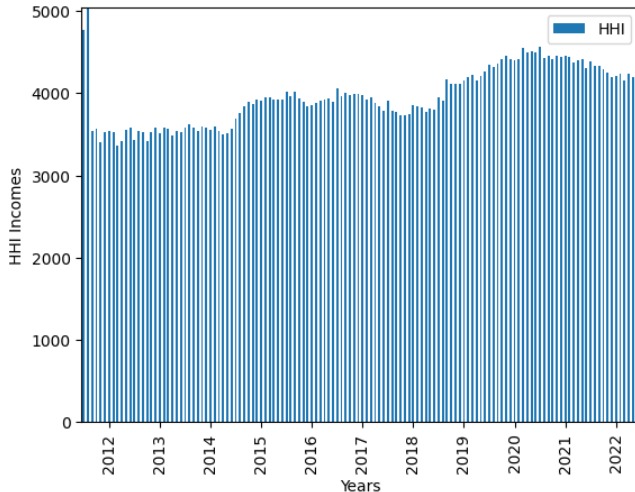


Figure 3. HHI for Mobile Services Incomes in Colombia.

In this case, the HHI has been increasing and is above 4000 in the last few years; results indicate a high concentration market and low competition in the income variable.

The third variable to analyze is traffic; the HHI for this can be seen in Figure 4.

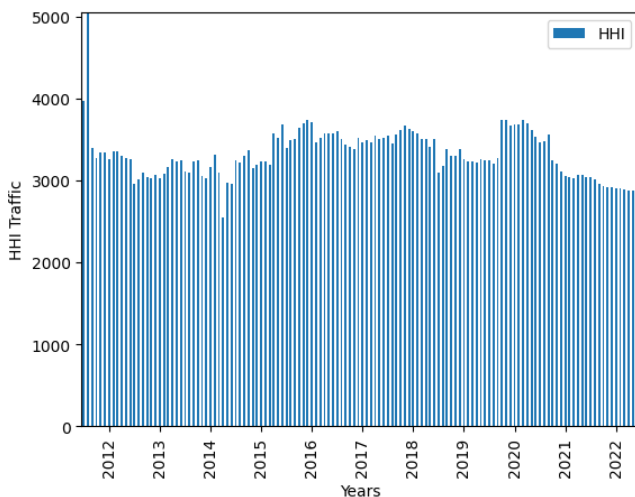


Figure 4. HHI for Mobile Services Traffic in Colombia.

In this case, the HHI has been decreasing and is close to 3000 in the last few years; results indicate a high concentration and low competition in traffic variables.

According to the results, the HHI is decreasing for access and traffic, but it is increasing for incomes, in three cases. The descriptive statistics for the HHI in the three variables can be seen in Table I.

TABLE I. DESCRIPTIVE STATISTICS OF HHI.

Statistics	HHI Accesses	HHI Incomes	HHI Traffic
count	132.0	132.0	132.0
mean	4069.667986	3965.84294	3324.645533
std	434.219881	346.304808	295.487329
min	3561.64898	3361.149037	2544.321017
25%	3759.728876	3619.170630	3100.544183
50%	3971.499849	3923.637351	3288.328112
75%	4266.036144	4237.804731	3516.755919
max	5621.046372	5045.727214	5053.229637
Kurtosis	1.587545	-0.556497	7.743688
Skewness	1.315731	0.315892	1.396602

The descriptive statistics of the results show that all the HHIs are above 3000, which indicate a low competition in the mobile services market and a high concentration. The results show a normal distribution shifted to the left with a maximum value higher than 5000 and a minimum value above 3000, except for the traffic HHI, which is 2544.

B. Stenbacka Index Results

For the Stenbacka index calculation, the two service providers with the highest value in accesses, incomes, and traffic are used, and the dominance can be estimated with the Stenbacka formula. The data is the same one used for the HHI calculation: mobile services data from postdata. The first variable to be used is accesses, referring to the users. The Stenbacka index for accesses can be seen in Figure 5.

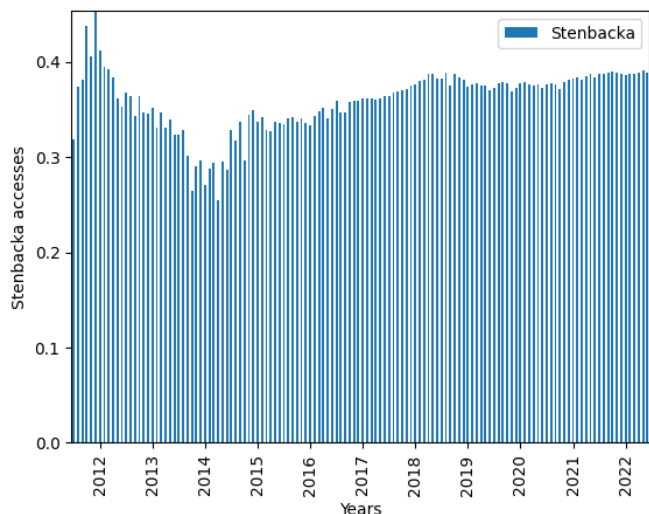


Figure 5. Stenbacka for Mobile Services Accesses in Colombia.

Results show that this index is close to 0.37 and the S_1 value for the service provider is above 0.5, which means that there is a dominant position for this service provider because S_1 is the first service provider and $S_1 > S_D$.

The second variable to be analyzed is mobile service incomes. The Stenbacka index calculated for this can be seen in Figure 6.

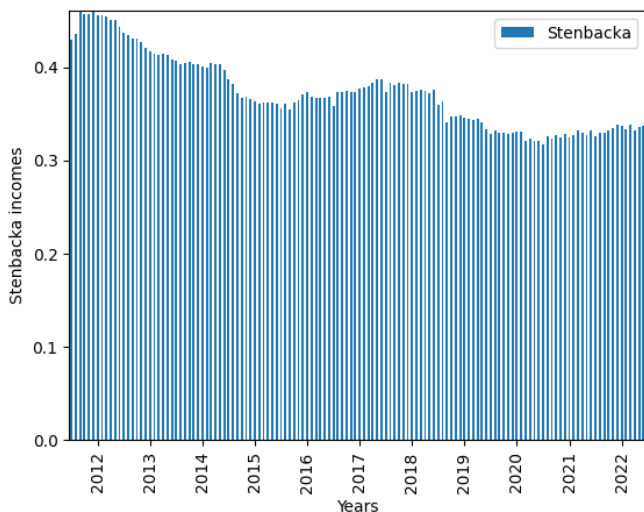


Figure 6. Stenbacka for Mobile Services Incomes in Colombia.

Results show that this index is close to 0.34 and the S_1 value for the service provider is above 0.5, which means that there is a dominant position for this service provider in mobiles service incomes, because S_1 is the first service provider and $S_1 > S_D$.

The third variable to be analyzed is traffic. The Stenbacka index for this can be seen in Figure 7.

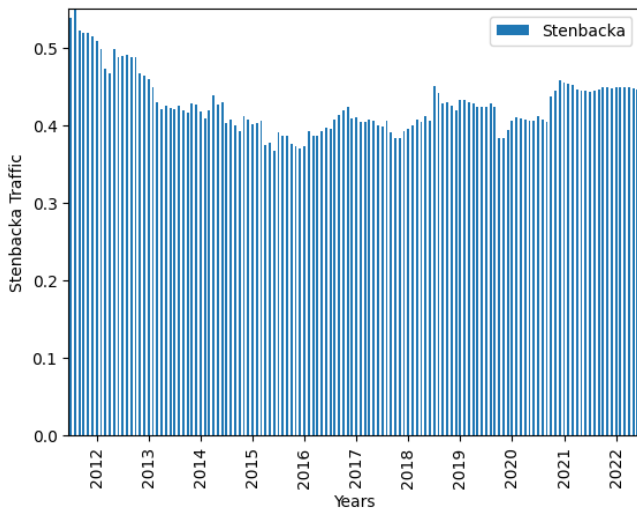


Figure 7. Stenbacka for Mobile Services Traffic in Colombia.

The Stenbacka index values, in this case, are higher than 0.4, and S_1 has been decreasing in the last years. The index has been very close to the S_1 value, and dominance level for this variable is decreasing.

The descriptive statistics for the Stenbacka index for the three variables can be seen in Table II.

TABLE II. DESCRIPTIVE STATISTICS OF THE STENBACKA INDEX.

Statistics	Stenbacka Accesses	Stenbacka Incomes	Stenbacka Traffic
count	132	132	132
mean	0.359569	0.372426	0.427974
std	0.031942	0.038746	0.036870
min	0.254502	0.316983	0.368424
25%	0.341244	0.336430	0.404884
50%	0.368436	0.368420	0.421389
75%	0.381526	0.401472	0.447730
max	0.453625	0.460762	0.551590
Kurtosis	1.425717	-0.475741	1.093329
Skewness	-0.798077	0.620616	1.057399

The descriptive statistics of the results show that all the Stenbacka index values are above 0.35, and for all cases, it shows a dominant service provider in the mobile services market. The results show a normal distribution shifted to the left for incomes and traffic and shifted to the right for accesses, with a maximum value higher than 0.5 and a minimum value above 0.25.

V. CONCLUSIONS AND FUTURE WORK

It is relevant for service providers and regulators to measure and detect the market conditions, regulations, and laws for mobile services in Colombia, to minimize monopoly practices and encourage the service provider’s competition.

The HHIs of mobile services accesses, income, and traffic demonstrate a high concentration, and low competition in this market in Colombia, which must be analyzed by government and regulatory authorities.

The Stenbacka index results for mobile services accesses, income, and traffic show that there is a dominant service provider in Colombia, but it also shows that, in the last few years, its level has decreased.

In consequence, the mobile services market in Colombia has a dominant service provider and a low level of competition in a highly concentrated market. This must be analyzed by authorities and regulators to improve the conditions of the mobile service for end-users.

In future work, more indexes can be calculated, and machine or deep learning techniques can be involved to predict market behavior and competition.

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