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ARTICLE

Innovation Ecosystem in Application Platforms: An Exploratory Study of The Role of Users

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ABSTRACT

Application platforms are part of innovation ecosystems where interactions between end users and developers self-regulate the growth of the ecosystem itself. One of the most important information for this process is user reviews. This paper uses one ordinary least squares (OLS) regressions for 2016, based on 20 variables for 60 countries to measure consumer demand, using a new indicator based on end-user assessments to verify consistency of relations between quality of demand (measured by the new indicator) and the innovative performance of different countries in this productive segment. The results show the robustness and the new research possibilities that arise, given the positives characteristics presented by the new indicator built by big data and data analytics tools. This indicator shows that the quality of demand supports innovations in the productive segment, which has led to the concussion that obtaining more sophisticated demand feedback represents a potentially powerful stimulus for advancing application development.

KEYWORDS: App store; Assessments; Innovation; Consumer market requirement.

1. Introduction

In the last decade, the amount of data generated by economic agents has expanded considerably. The increase in the volume of available data is explained by the diffusion of information and communication technologies (ICTs), mainly smartphones and the apps market (GANAPATI; REDDICK, 2018). The increasing use of mobile devices, the spread of wireless broadband, smartphones and sensors connected to the Internet have resulted in the emergence of an ecosystem of innovation through the emergence of digital application platforms, or simply apps (BALDWIN; WOODARD, 2009; TIWANA, 2014; VAN ROOYEN *et al*., 2013).

Smartphones with location and monitoring sensors capture user location information in real time, and this information is used to provide various customized services (GANAPATI; SHAPIRO; WALKER, 2016). Currently, there are chemical, radar, pressure, temperature, flow and humidity sensors, gyroscopes and magnetometers. Along with the growing cheapness and ubiquity of these sensors came the exponential growth of applications, providing oceans of data, opening up new and different possibilities of analysis (ARTHUR, 2017). There are already applications consisting of dozens and even hundreds of sensors connected to wireless networks, used to report the presence of objects or chemicals, current position and changes in conditions outside a system.

As demonstrated by the Platform-based Innovation Ecosystems literature (VAN ROOYEN *et al.* , 2013), applications use the Internet to supply digital platforms with data and generate information that enables the establishment of connections between people and businesses over time and space. The platforms are responsible for collecting, processing and storing the data generated. They also provide the technological infrastructure necessary to promote interaction, using the data produced to provide different services (EVANS; SCHMALENSEE, 2016).

As a result, more and more applications are helping people out to perform their routine tasks, while their customers pass on to suppliers information about features that can be improved, generating news. In fact, the importance of the relationship between users and producers for innovation processes is not a new element in the innovation economics literature. Among the main characteristics of this relationship pointed out by Lundvall (1988), the following seem to be especially relevant to the application market a) the production of knowledge through "learning by using", which can be transformed into new products if producers have direct contact with users; and b) the monitoring of skills and potential knowledge developed by users, which can be of great interest to producers to check their ability to adapt to new products. It is true that in the contemporary context, innovations resulting from app user evaluations tend to be more incremental in nature than a high degree of novelty. This is because the feedback provided by users lead to improvements in existing functionality - or even the creation of new ones, but in existing applications. Nevertheless, as the relationship found in this article between user feedback and application patenting shows, new products and significant advances in certain technological trajectories can be inspired or derived from such feedbacks.

From an academic point of view, the vast amount of data generated by applications can be used to monitor the behavior of agents and to raise and test hypotheses covering different areas of scientific thought. They also open up opportunities to analyze hypotheses that were impossible to test so far, offering access to new data on consumer behavior and even replacing traditional sources whose data is of lower quality. On the other hand, the use of large databases through the application of *big data* tools and *data analytics*, currently available for studies in the field of applied social sciences, represents a trend that can significantly contribute to the advancement of research[1].

Regarding the market of applications, the App Store (Apple's application marketplace) marks the emergence of the first market specialized in the area. Among the different data generated in the App Store, we highlight the users' evaluations, which have two distinct evaluation instruments, namely: 1) the comments of the other users, and 2) a rating system, in which they can give ratings from one (bad) to five (great) stars.

Although user evaluations on the App Store result in the emergence of a wide range of data on consumer behavior, this data remains underutilized. As we were able to ascertain during the literature review of this study, no research was found that would use user assessments to construct indicators regarding consumer market characteristics for different countries. The currently widely used benchmark is the World Economic Forum (WEF) Quality of Demand Conditions Index. This indicator, together with eleven other pillars, measures the degree of competitiveness of each country, based on Porter's competitive diamond model (1998a; 2001). The development of an indicator capable of measuring the level of demand represented a major advance for the innovation literature. See that demand "[...] can create

1 The present study, using a large database generated by Platform-based Innovation Ecosystems, adheres to this trend (EINAV; LEVIN, 2014; JIN et al. 2015; VICENTE; LÓPEZ-MENÉNDEZ; PÉREZ, 2015; BLAZQUEZ; DOMENECH, 2018a, 2018b).

an important competitive advantage as it forces companies to be more innovative and customer-oriented", which raises the level of market efficiency (WEF, 2017, p. 2). Thus, it is recognized the importance of the indicator developed by WEF for the advancement of research alluding to the effects of demand conditions on economic variables, due to its wide use to measure the degree of innovation and competitiveness of countries (WONGLIMPIYARAT, 2010; VARES *et al.* , 2011; SAVIĆ, 2012; ÇINICIOĞLU *et al.* 2013; KORDALSKA; OLCZYK, 2015, 2016; KOREZ-VIDE; TOMINC, 2016; AKPINAR; CAN; MERMERCIOGLU, 2017; ERKAN; GÜDÜK; KESKIN, 2018; KONTIC, 2018; OLIMPIA, 2019; TAMBADE; SINGH; MODGIL, 2019).

Despite its advantages, the Quality Index of Demand Conditions is not data intensive, being elaborated based on specialists' perception, presenting problems such as subjectivity and low variability, which makes the use of quantitative analysis tools difficult (PORTER *et al.* , 2008; SALA-I-MARTIN *et al.* , 2011, 2012, 2013; SCHWAB, 2013). The dissemination of this indicator, associated with its limitations, justifies the development of a more robust indicator, through the application of Data Science intensive tools in data declared by consumers themselves. Thus, a window of opportunity is opened so that the evaluations of the application market users can be used to build more quantitative indicators, capable of capturing with greater objectivity the characteristics of the consumer market of different countries.

Given this context, this article has two objectives. The first is to use *big data* and *data analytics* tools to measure the degree of consumer market demand, employing a new indicator based on end-user assessments. The second objective is to verify the consistency of relationships between the quality of demand (measured by the new indicator) and the innovative result (measured by app patents). We thus test whether the customer-supplier relationship, indicated by the literature as one of the main sources of innovation, is corroborated for the applications market, based on the built indicator (AMARAL; TOLEDO, 2000; CAMELO; COELHO; BORGES, 2010; GOBARA *et al.* , 2010; LUNA; KRICHELDORF, 2011; VANALLE, 2011; CARDOSO, 2012; DIAS, 2014; SQUEFF, 2015; DAL BÓ *et al.*, 2017; VIANNA, 2017; DA COSTA NETO; PERIN; FERREIRA, 2019; ZORZENON, 2019). The new indicator is compared to the traditional Demand Conditions Quality Index, in order to reveal its robustness. The hypothesis being tested is that the level of demand in the consumer market, measured by the constructed indicator, influences the degree of innovation in countries, measured by an indicator of the number of patent applications related to the creation of mobile applications. The regression was estimated based on data from 60 countries for the year 2016.

In addition to this introduction, the article has four sections. In section 2, a review of the Digital Platform Ecosystems literature will be performed and some data regarding the application market will be presented. In the following, section 3 will formalize the methodology used to build the consumer market demand indicator. Later, in section 4, the results obtained for the constructed indicator will be presented and the above-mentioned regressions will be estimated. Finally, in section 5, some final considerations are made.

2. Innovation ecosystems and digital platforms

Innovation ecosystems can be seen as new ways of organizing goods and services through the interaction of many companies with complementary skills, who collaborate and compete to offer more complex goods and services, which are subject to greater customization according to the feedbacks offered by consumers, made possible by digital tools (JACOBIDES; DREXLER; RICO, 2014).

Given the high adaptability, dynamism and interactivity of ecosystems, the specialized literature now calls them ecosystems of innovation. Jackson (2011) defined an innovation ecosystem as “the complex relationships that are formed between actors or entities whose functional objective is to enable technological development and innovation” (JACKSON, 2011, p. 2). Autio and Thomas (2014) refined this definition by emphasizing that an innovation ecosystem has “a network of interconnected organizations, organized around a company or focal platform, and incorporating both production and participants on the use side, and focusing on the development of new values through innovation” (AUTIO; THOMAS, 2014, p. 3).

Specifically, the Platform-based Innovation Ecosystems (PIE) literature argues that agents create entire ecosystems, usually around products or a platform (VAN ROOYEN *et al.*, 2013). Around it, there is concertation and orchestration of agents, promoting the development of a feeding ecosystem (BULLINGER *et al.*, 2012; SHAW; ALLEN, 2016), characterized by the emphasis on learning and experimenting with social and technological solutions (DROR *et al.*, 2015).

As highlighted by Jacobides, Drexler and Rico (2014), PIE can encompass any set of interacting producers, suppliers, innovators, customers and regulators responsible for generating a collective result. In more precise definition, digital ecosystems are interactive organizations that are digitally connected and empowered by modularity, without a hierarchical authority responsible for carrying out management. In these ecosystems, organizations come together specializing in different functionalities, creating bonds that generate collaboration, in an environment permeated by intense Schumpeterian competition, conducive to the development of innovations.

A PIE consists of two main elements: a platform and complementary applications transacted through this platform (GROBBELAAR; URIONA, 2020). For Jacobides, Drexler and Rico (2014), platforms can be understood as the shared infrastructures, used by applications to generate value by providing functionality. The applications access, develop and expand the platform's functionalities through a set of interfaces that allow communication, interaction and interoperability with the platform. At the same time, according to Baldwin and Woodard (2009) and Tiwana, Konsynski and Bush (2010), the platform serves as a foundation upon which agents can create complementary products or services to each other, configuring themselves as an extensible system through their own interaction with the applications (TIWANA, 2014).

In addition, there are three other contextual resources related to PIE: end users, rival platform ecosystems and the competitive environment that permeates interactions. End users are the collection of existing and future consumers of the services and products offered through the platform. A platform ecosystem exists within a larger competitive environment, often competing with other rival platform ecosystems. These ecosystems compete constantly, both for users and application developers. Competition rarely occurs directly between platforms, but between ecosystems themselves. The more intense the competition, the more important it becomes how the platform evolves, so the presence of a vibrant and dynamic ecosystem is the main determining condition for the survival and expansion of platforms and the products and services provided (TIWANA, 2014).

The PIE literature tends to consider ecosystems as complex adaptive systems, i.e. systems in which cumulative causation produces growth, self-regulation or stagnation. This makes the platform's structure useful by including the evolutionary characteristics of interactions between individuals, their relationships and relationships with the components of the ecosystem as responsible for determining their evolution, also including issues such as open innovation, capacity development in actors (DURST; POUTANEN, 2013; TURA; KUTVONEN; RITALA, 2018) and the influence of user assessments.

User comments and evaluations are used as quality control tools for the services and products offered in digital form. Launched by eBay in the mid-1990s, user assessment is now adopted by most digital platforms as a self-regulatory mechanism, leading to the creation of the concept of "online reputation" (JACOBIDES; DREXLER; RICO, 2014). Given the presence of two distinct sides participating in a digital transaction, user assessment systems help establish trust and decrease perceived risk (SCHREIECK *et al*., 2018) by building metrics (VAN WELSUM, 2016; BOTSMAN, 2017).

The fact that users can evaluate the applications, products and solutions offered means that the worst quality services are penalized and expelled from the digital marketplace. As a result, the evaluation system reduces the need for agents responsible for regulating the market (SUNDARARAJAN, 2016). Examples of this practice are Uber and Airbnb, with their assessment systems that allow users to identify and report opportunistic behaviors, which makes the platforms able to identify reported users and prevent them from using them again (THIERER, 2015). Thus, assessments influence the need for companies to adapt and develop better quality solutions. Thus, the degree of consumer demand, in the presence of assessment systems, in addition to enabling self-regulation by means of reputational metrics, as placed by Sundararajan (2016), Van Welsum (2016) and Botsman (2017), may result in a greater need for innovation in these ecosystems.

The pressure generated by demand conditions, which drives firms to innovate, is a fact widely reported in the innovation literature (BOON; EDLER, 2018), since its proposition by Schmookler (1966), and corroborated mainly for high-tech products and manufacturing industries (JUSTMAN, 1994; PORTER, 1998b; BÖNTE, 2004; FABRIZIO; THOMAS, 2012; LÜTHJE; HERSTATT; VON HIPPEL, 2005; EVANSCHITZKY *et al*. 2012; KUTSCHKE; RESE; BAIER, 2016; MOEN; TVEDTEN; WOLD , 2018; MYERS; PAULY, 2019). In other words, in markets with more demanding consumers, intense feedback on solutions developed by ecosystem companies generates more pressure on companies, which can help explain even the differences in innovation rates between countries.

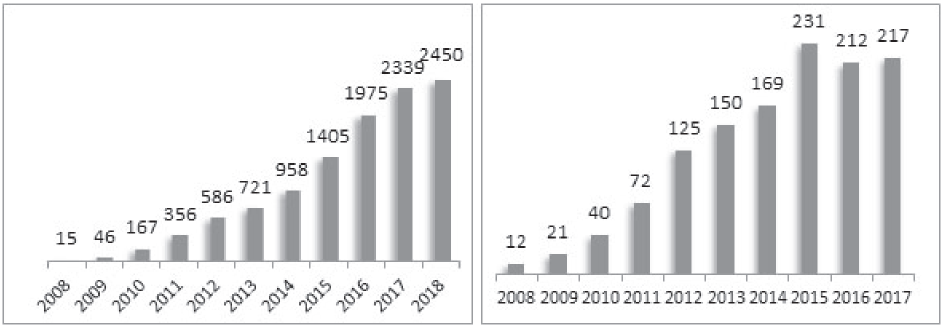
3. Methodology

3.1 Application market context

The app market emerged on July 10, 2008, after the launch of the iPhone, with the creation of the App Store. The launch of the App Store represented a disruptive change, as it allowed developers to freely trade applications, which contradicted the previous logic, in which mobile phones already came from the factory with a pre-determined set of applications, and it was not possible to freely modify the applications used.

The number of apps available to download on the App Store (Graph 1, left) shows that the market for apps grew exponentially over 2008-2018, from just 15,000 apps to download in 2008 to 2,450,000 in 2018. The number of iPhones sold (Graph 1, right) also grew sharply, mainly over the period 2008-2015, from 12 million devices in 2008 to 231 million in 2015.

GRAPH 1
Evolution in the number of apps for download on the App Store, in thousands (left) and iPhone sales, in millions (right)

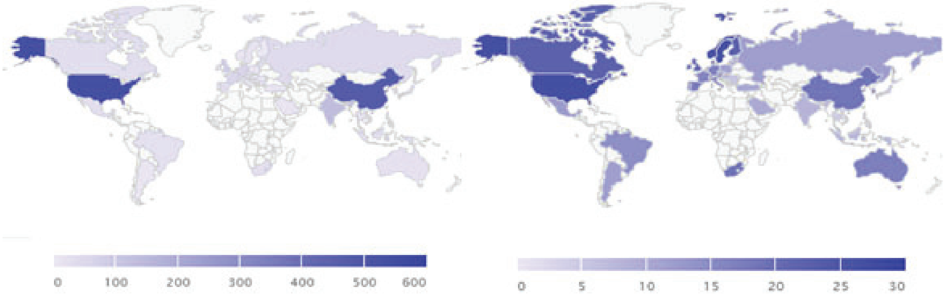


Source: Statista.

Analysis of the app market shows that the revenue generated (Figure 1, left) is concentrated in a few countries. The five countries with the largest market for applications in 2018 were: the United States, with US$ 536 million (29% of world revenue); China, with US$ 473 million (26%); India, with US$ 135 million (7%); the United Kingdom, with US$ 84 million (5%); and Germany, with US$ 58 million (3%). On the other hand, the penetration of users in the application segment between countries occurs in a more equal way, as it is visible in the panel on the right.

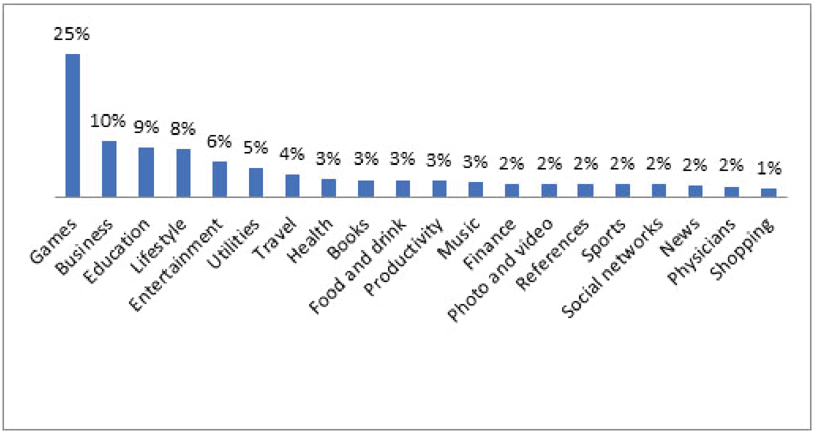
Application downloads (Graph 2) are scattered among the 20 categories considered by the Sensor Tower. The most downloaded categories were games (25% of downloads), business (10%), education (9%) and lifestyle (8%).

FIGURE 1
Revenues, in millions (left), and user penetration in the world application segment (right), in 2018.



Source: Statista.

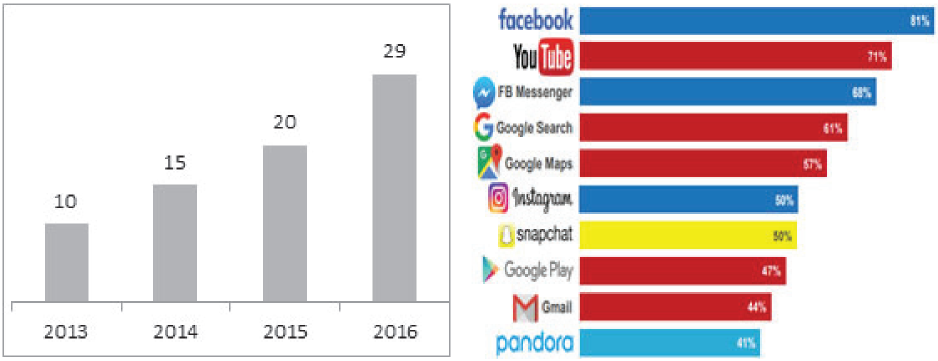
GRAPH 2
Percentage of application downloads in September 2018, by category



Source: Statista.

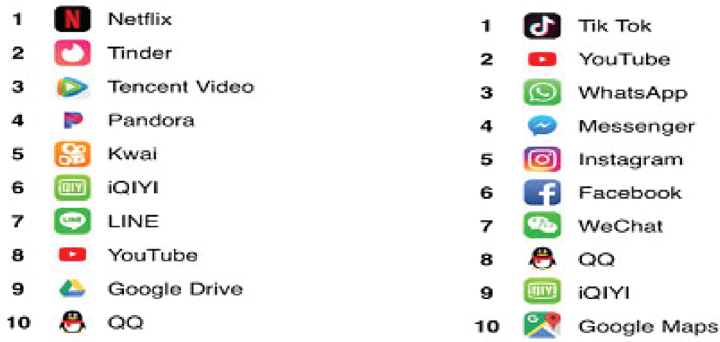
App Store sales revenues (Graph 3, left panel) were US$ 10 billion in 2013 and rose to US$ 29 billion in 2016, showing the consistent progress made by this market. However, only two companies (Graph 3, right panel), Facebook (with Facebook, Messenger and Instagram) and Google (with Youtube, Google Search, Google Maps, Google Play and Gmail), account for eight of the 10 most downloaded applications in 2017. Only Snapchat and Pandora did not belong to those companies, which shows the high concentration of that market.

GRAPH 3
Annual App Store sales revenue, 2013-2016, in billion US dollars (left) and degree of penetration of the 10 most downloaded applications in 2017 (right)



Source: Statista and ComScore.

FIGURE 2
Ranking of the applications with the highest sales revenue in the App Store (left) and with the highest number of downloads, except games, in the first quarter of 2018 (right).



Source: Sensor Tower.

The applications with the highest App Store sales revenue (Figure 2, left panel) in the first quarter of 2018, except games, were Netflix, Tinder, Tencent Video and Pandora. The most downloaded applications in the same quarter of 2018 (Figure 2, right panel) were Tik Tok, YouTube and WhatsApp.

3.2 Prior setup of the database

The biggest challenges of this survey were obtaining reliable data regarding the evaluation of the applications by the users and the development of an indicator of consumer market demand. After extensive search and analysis of different databases, it was decided to use the data provided by the Sensor Tower.

This platform, created in 2013, specializes in the analysis of the application market, providing data relating to different metrics for measuring this market, including: 1) the ranking of the most downloaded applications, broken down by application, category, form (paid or free), period and country; 2) sales revenue, broken down by application and by company; 3) the history of user assessments, broken down by application and country, including the score assigned by users; and 4) the percentage of users of the application in the countries where it is most used.

For the construction of the Consumer Market Demand Index, users' evaluations were collected in a careful way, taking several precautions so that the data collected were not biased and were not influenced by idiosyncratic factors related to the applications or countries, namely:

- **Addition of applications:** the data used refers only to the 10 most downloaded applications from each of the 23 categories discriminated by Sensor Tower. A critical analysis of the applications that were not among the most downloaded was also performed in order to identify other relevant applications.
- **Elimination of applications:** applications that are not present in a high number of countries, with less than 100 evaluations, used only in specific regions of the planet and with high variability in evaluations were excluded from the sample.

After applying the above criteria, the number of applications in the sample was reduced from over 200 to only 28: Facebook, Snapchat, Airbnb, Gmail, Dropbox, Google Maps, Google Chrome, Google, Google Translate, Tinder, Pinterest, Messenger, Linkedin, Google Hangouts, Audible audiobook, Duolingo, Photo math, Pokémon Go, Candy Crush Saga, Clash Royale, Angry Birds Go, Spotify, Soundcloud, Waze, Google Drive, Outlook, Microsoft Word and Uber.

The initial sample consisted of more than 100 countries, but most had few evaluations, which meant that 40 countries were removed from the database.

After all the sample construction and preparation procedures were carried out, it was now comprised of a three-dimensional matrix that identifies the evaluations of 28 applications in 60 countries for five categories (from one to five stars), totaling 10,376,680 evaluations. The final sample consists of the following countries: United States, Great Britain, Italy, Mexico, Germany, Canada, France, Brazil, Japan, Australia, Taiwan, South Korea, Thailand, Peru, Spain, Vietnam, Netherlands, India, Philippines, Malaysia, Sweden, Russia, Chile, Singapore; Hong Kong, Denmark, Indonesia, Switzerland, Belgium, Argentina, Colombia, Israel, United Arab Emirates, Norway, Greece, Turkey, Saudi Arabia, Poland, Romania, Egypt, Pakistan, New Zealand, Ireland, Hungary, Austria, Portugal, Venezuela, South Africa, Ecuador, Ukraine, Czech Republic, Dominican Republic, Guatemala, Finland, Costa Rica, Bulgaria, Kuwait, Croatia, Slovakia and Uruguay.

3.3 Construction of the Indicator

The Consumer Demand Indicator was built from a three-dimensional matrix consisting of N=60 countries, K=28 applications and I=5 different assessments (1, 2, 3, 4 or 5 stars). The element x_{ijl} of the respective matrix identifies the number of appraisals for i application stars l in the country j.

The Consumer Demand Indicator is built in four steps. In the first step, the proportion of negative assessments is identified α_{jl} received by the application l in the country j. The number of evaluations with one and two stars received by the application is used to measure the negative evaluations:

$$\alpha_{jl} = \frac{x_{1jl}+x_{2jl}}{\sum_{i=1}^{I} x_{ijl}}. \tag{1}$$

In the second step, the total proportion of negative evaluations received by the application is calculated in relation to the total number of evaluations:

$$\beta_l = \frac{\sum_{j=1}^{N} x_{1jl}+\sum_{j=1}^{N} x_{2jl}}{\sum_{i=1}^{I}\sum_{j=1}^{N} x_{ijl}}. \tag{2}$$

The third step consists of dividing the proportion of negative evaluations of the application received in the country (step 1) by the total proportion of negative evaluations received by the application (step 2):

$$\gamma_j = \frac{\alpha_{jl}}{\beta_l} = \frac{\left[\dfrac{x_{1jl}+x_{2jl}}{\sum_{i=1}^{I} x_{ijl}}\right]}{\left[\dfrac{\sum_{j=1}^{N} x_{1jl}+\sum_{j=1}^{N} x_{2jl}}{\sum_{i=1}^{I}\sum_{j=1}^{N} x_{ijl}}\right]} \tag{3}$$

This step relativizes each country's negative assessment against the negative assessment received by the application, filtering out application-specific information.

Only information remains responsible for identifying whether consumers in the country have penalized the application more than other countries. When consumers penalize the application more severely γ_{ijl} , is higher than 1, indicating that consumers are more demanding than average. On the other hand, when consumers penalize the application in a lenient way γ_{ijl}, is less than 1, showing that consumers are less demanding than the average of the countries.

Later, to eliminate idiosyncratic factors related to the applications, the arithmetic average of the evaluations received by the K applications in each country is calculated:

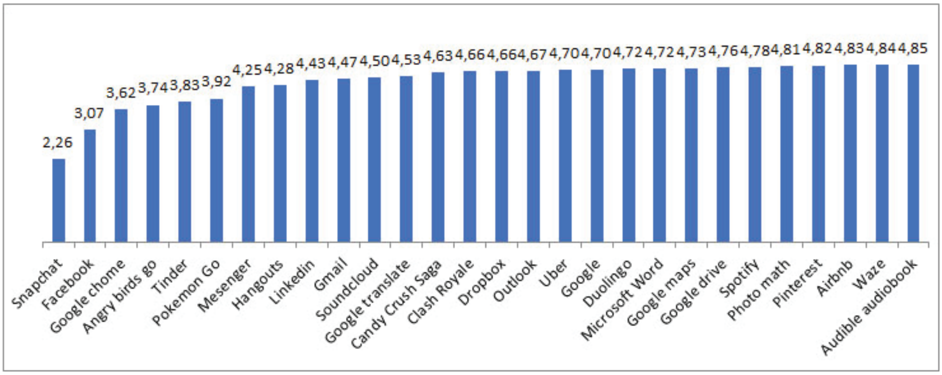
$$\omega_j = \frac{\sum_{l=1}^{K} \gamma_j}{K} \tag{4}$$

4. Assessment of the new indicator

4.1 Analysis of the indicators

Graph 4 displays the assessment of each of the applications used to build the Consumer Market Demand Indicator (Gamma Index). A considerable part of the applications (18) have an evaluation of more than 4.5. Only six applications have a rating of less than 4.00: Snapchat (2.26), Facebook (3.07), Google Chrome (3.62), Angry Birds Go (3.74), Tinder (3.83) and Pokémon Go (3.92).

GRAPH 4
Evaluation of the applications used to build the Consumer Market Demand Indicator



Source: Sensor Tower.

Table 1 presents some descriptive statistics found for the Omega Index, which measures the degree of demand in the consumer market. The average of the countries for this index is 0.854, being slightly lower than the median (0.868), since it assumes values between 0.481 and 1.361. The distribution of the Omega Index presents positive asymmetry, 0.287, so that the Average >= Median >= Fashion. Kurtosis is below zero, -0.912, indicating that the Omega Index has a flatter distribution than the normal distribution. Moreover, the Jarque-Bera test indicates that this index has normal distribution, because the returned value (2.752) is lower than the critical value (5.107) of the Chi-square distribution.

TABLE 1
Descriptive statistics, Omega Index

Statistics	Value	Statistics	Value
Average	0,854	Kurtosis	-0,912
Standard error	0,030	Asymmetry	0,287
Average	0,868	Break	0,880
Standard deviation	0,233	Minimum	0,481
Variance of the sample	0,054	Maximum	1,361
Jarque-Bera (value)	2,752		

Source: Own elaboration.

Table 2 presents the results found for the correlation between the number of patent applications related to the creation of mobile applications (hereinafter referred to as Patents in mobile applications) against the other variables. The percentage of R&D spending, GDP per capita and ICT use are the highest correlated with the innovation indicator on the agenda: 70%, 66% and 64%, respectively. In the sequence are Human Capital (64%), Technological Readiness (64%), and High Education and Training (63%). The smallest correlations are registered for Market Size (14%), Population (-19%) and Exchange Rate (-21%).

On the other hand, the variables that present the highest correlation with the Omega Index are infrastructure (68%), per capita GDP (65%) and number of patent applications (64%). While those with less correlation are economic openness (29%), population (7%) and exchange rate (-27%). The Omega Index also shows a high correlation with the quality of demand conditions (53%).

Thus, the indicator created presents a high correlation with the official indicator of the level of demand in the consumer market elaborated by the World Economic Forum and with the Patents in mobile applications, besides being able to explain in a more satisfactory way the innovation performance carried out by the countries (correlation of 64% against correlation of only 54% of the quality of demand conditions).

TABLE 2
Correlation of variables under analysis with the number of patent applications in mobile applications

(%)

Variable	Creation of mobile applications	ômega	Variable	Creation of mobile applications	ômega
Patents	100	64	Expected Years of Schooling	48	43
R&D spending	70	36	Internal credit to the private sector by banks	46	52
per capita GDP	66	65	Quality of demand conditions	43	53
Use of ICT	64	52	Labour market flexibility	35	44
Human Capital	64	53	Capitalization of listed companies	32	33
Technological readiness	64	52	Economic openness	24	29
High education and training	63	57	Market size	14	40
Infrastructure	58	68	Population	-19	7
Individuals who use the Internet	56	53	Exchange Rate	-21	-27
Omega Index	52	100			

Source: Own elaboration.

In addition, the Omega Index has advantages when compared to the Demand Conditions Quality Index. First of all, it is not built on the experts' perception of the market (SCHWAB, 2013), but on the preferences revealed by consumers themselves. Each consumer, when evaluating the services, provides data on their level of demand, without the need for subjective expert opinions. As the applications analyzed present a high degree of standardization, given that the methodology used helps reduce the weight of idiosyncratic factors, the comparison between countries reveals which markets have more demanding consumers.

Secondly, the Omega Index, unlike the Demand Conditions Quality Index, is not built on a Likert scale. It shows high variation and, in addition to identifying how consumer preferences vary between countries, it also shows how those preferences change over time. As a result, the Omega Index presents a much richer and more detailed set of information.

The results found in this subsection show that the index created to identify the level of demand of the consumer market has a high relationship with the level of economic development of the countries. The next subsection estimates a regression in order to verify whether the indicator created helps to explain the degree of innovation in countries and to identify what factors influence consumer demands.

4.2 Analysis of estimated regression

After the construction of the indicator measuring the degree of demand in the consumer market, Equation (4), a regression by the ordinary least squares method is estimated to verify whether the Omega Index influences the result in terms of innovation in countries, measured by the logarithm of the number of patent applications in mobile applications, p formally:

$$p_j = a_1 + a_2\omega_j + \sum_{s=3}^{S} a_s C_s + \varepsilon_j, \qquad (5)$$

whereby ω_j is the Omega Index for the country j; C_s is a vector composed of S-2 control variables; a_1, a_2 e a_s are the parameters to be estimated and ε_j is the term of error.

Table 3 presents the variables used to check which factors influence consumer preferences and to test whether these preferences determine the level of innovation in countries. The database built has 19 variables raised for 60 countries for the year 2016, from different sources, with emphasis on:

- World Intellectual Property, created by the United Nations in 1967 to protect intellectual property by making available data on patents registered by different countries;
- Global Competitiveness Report, prepared by The World Economic Forum to analyse the degree of competitiveness of countries;
- Heritage, which provides data related to the countries' business environment;
- UNESCO, established to promote peace and intellectual cooperation among nations; and

- World Bank, which is currently one of the largest international sources for promoting economic development, also has one of the largest and most comprehensive databases, broken down for different countries.

TABLE 3
Variables used in the estimated regression

Variable	Source
Omega Index	Own elaboration
Patents on mobile applications	World Intellectual Property Organization
Individuals using the Internet (% of population)	World Bank
GDP per capita purchasing power parity (2011 dollars)	World Bank
Domestic credit to the private sector by banks (% of GDP)	World Bank
Economic openness: (imports + exports)/ GDP	World Bank
Capitalisation of listed companies (% of GDP)	World Bank
Population (logarithm)	World Bank
Exchange Rate	World Bank
R&D spending (% of GDP)	World Bank
Market size	Global Competitiveness Report
Labour market flexibility	Global Competitiveness Report
Infrastructure	Global Competitiveness Report
High education and training	Global Competitiveness Report
Technological readiness	Global Competitiveness Report
Use of ICT	Global Competitiveness Report
Quality of demand conditions	Global Competitiveness Report
Human capital	UNESCO
Years of schooling expected	UNESCO

Source: Own elaboration.

The database was built in order to identity the main factors that influence demand conditions, classified in six dimensions: 1. The factors related to the demand size – GDP and market size; 2. Quality of users – quality of demand conditions, human capital, expected years of formal education and higher education and training; 3. Degree of sophistication of the productive structure – Index of Economic Complexity, infrastructure and flexibility of labor market; 4. the degree of technological development of the country – R&D expenditures, technological readiness, use of ICT, number of patent applications and individuals using the Internet; 5. the degree of development of financial institutions - domestic credit to the private sector by banks, capitalization of listed companies and interest rates; 6. the degree of openness and development of national institutions - labor market flexibility and economic openness; and 6. the control variable - population.

The estimated regression (Table 4) has as explained variable the logarithm of the indicator of number of patent applications related to the creation of mobile applications, for the year 2018, being estimated against the Omega Index and a set of selected variables. The Breusch-Pagan test indicates that it presents heteroscedasticity, a problem solved with White's robust estimator. The estimated coefficients for the number of patents related to the creation of mobile applications show that the use of new information and communication technologies and the size of the market have a positive influence.

TABLE 4
Results found for the estimated regression, independent variable: logarithm of the indicator of the number of patent applications in mobile applications

Variable	Coef.	Std.	Variable	Coef.	Std.
Omega Index	17,835(2)	7,102	R&D spending	3,716	3,13
Use of ICT	8,448(2)	2,578	Capitalization	-0,042	0,036
Market size	4,284(1)	2,492	Exchange Rate	-0,001	0,001
Human capital	-0,594	0,551	Constant	-12,058	39,673
F	27,14				
R2	0,853				
Breusch-Pagan	1,86 (0,173)				

Source: Own elaboration.
(1) significant at 90%.
(2) significant to 95%, Std. is the standard error. The variables not presented showed coefficients that were not significant.

The Omega Index is significant for the 90% and 95% confidence level for the regressions that have the logarithm of the number of patents and the creation of mobile applications as explanatory variables, respectively: the presence of a more demanding consumer market results in a higher number of patent applications. Moreover, the Omega Index proved more robust than the Quality of Demand Conditions (SCHWAB, 2013), which was not significant even when the Omega Index was removed from the estimated regression. This result presents evidence in support of the argument that the indicator created is more robust than that developed by the World Economic Forum. That is, by using empirical data regarding the preferences declared by users themselves, it is able to better measure the effect of the level of consumer demand on the innovation performance of countries (better than an index created based on expert opinion, such as the Quality of Demand Conditions).

These results are in line with the PIE literature, which considers that these ecosystems are endowed with high dynamism and adaptive capacity. As demonstrated by Tiwana (2014), complementarity and intense competition among the companies present in these ecosystems provide them with high dynamism and capacity for innovation. Such ecosystems organize goods and services through the interaction of many companies with complementary skills, and the comments offered by consumers are important in determining how services evolve (JACOBIDES; DREXLER; RICO, 2014; SCHREIECK *et al.*, 2018).

However, the results found for this regression need to be relativized. Among the countries with the largest population, only Indonesia, Brazil, Pakistan and Nigeria remained in the sample. The most populous countries (China and India) were excluded because they did not meet the requirements - China, for example, due to the high closure of its economy and technological incentive policy, uses its own applications, which explains its exclusion from the sample[2].

In addition, the result found for the exchange rate calls for caution, since this variable is not significant for the regression that has the number of patent applications related to the creation of mobile applications as an explanatory variable. The experiences of China and India show that countries do not necessarily need to resort to economic openness and exchange rate appreciation to develop a competitive market for applications. India, on the one hand, being an important global player,

2 Therefore, among the next steps of this survey is the construction of a new sample of applications that will enable the calculation of the Omega Index for these countries, which will enable a more reliable identification of the relationship between the level of demand of the consumer market and the size (qualification) of the country.

in order to be competitive, needs to ensure the quality of the applications, since the external demand generates pressure on producers, which raises the quality of the applications produced. China, on the other hand, imposes restrictions on the import of applications for cyber security reasons. However, the relative closure of the economy and the devalued exchange rate do not imply low quality in the applications produced in the country. The high internal market, the technology policy to encourage the emergence of startups in new technologies and the presence of legislation stimulating the emergence and competition of innovation ecosystems based on digital platforms (BIGGS *et al*., 2017) contribute to raising the quality of applications produced. That is, through the right mix of incentives, a country can develop competitive digital platform ecosystems without having to resort to the opening up of its economy, as long as it adopts an appropriate set of policies. More than that, one must always consider the time when the exchange rate remains devalued so that exports can reach a higher level. In technological terms this would be the time to learn about the new potential demand, i.e. learning by exporting (BLALOCK; GERTLER, 2004)

Still on the estimated regression for the Omega Index, the greater flexibility of the labor market has a positive influence on the level of consumer demand. In other words, consumers become less complacent about providing poor quality services. The intuition behind the indicator is that the greater possibility of job losses and the need to do work properly make consumers more demanding with products purchased from other firms. Similarly, the presence of a more developed infrastructure raises the level of demand from consumers, who become more used to urban amenities.

5. Conclusions

This article used user assessments to propose an indicator of the level of consumer demand, so that deductions could be made about the potential of consumer feedback from different countries on the process of application innovation.

The descriptive statistics show the great expansion and high dynamism observed in the income and number of consumers of innovation ecosystems. However, they also show a strong concentration of the most downloaded applications in the period reviewed (2013-2018) in only two ecosystems: Facebook and Google. This concentration of applications in specific ecosystems may compromise competition, illustrating, therefore, a phenomenon still little analyzed in the Brazilian literature of innovation economics, which points to a field for further studies.

The indicator constructed in this survey proved to be superior to the one traditionally used in the area, because it has a lower level of subjectivity and presents a greater variation, pointing to the presence of greater accuracy in statistical inferences. It provides an instructive set of information that can be used to assess how consumer preferences vary over time and space and to design and perform more robust and specific hypothesis testing. In addition to providing more powerful insights into how the characteristics presented by consumers (the conditions of demand) influence and are influenced by economic variables such as innovation, competition, economic openness, diversification and sophistication of the production structure.

To test its statistical robustness, a set of analyses was performed. Initially, we saw the positive and high correlations with intuitively related variables: the quality of demand conditions (69%), per capita income (65%) and the number of patent applications from each country in mobile applications (64%). The robustness was reinforced by the estimation of a regression, aimed at testing the hypothesis that the level of demand of the consumer market, measured through the constructed indicator, influences the degree of innovation of the countries, obtained from the logarithm of the number of patent applications in mobile applications. The results obtained corroborated the hypothesis raised.

These results have led to the understanding that getting feedback on the most sophisticated demands represents a superior stimulus to advancing incremental innovation and application improvements over demand from less developed countries. Assuming the trend of cumulative causation in ecosystems and that local problems are usually the object of application developers' efforts, this result suggests that part of the application segment of less developed countries, such as Brazil, may have its development locked in (lock-in) by the less sophisticated demands to which it is subjected.

In addition, the results of this exploratory study should lead to the elaboration of hypotheses around the factors that explain the quality differentials of demand as determinants of the capacity to innovate in applications. Nevertheless, it is understood that these new hypotheses now have a more powerful tool for statistical[3] testing.

3 It should be noted that the results found for the estimated coefficients are subject to the presence of umbilical relations among the variables: countries with more qualified and demanding applications are also countries of higher economic development, not only because they are on the frontier of knowledge, but also because they house a large number of highly qualified people, especially in the areas of knowledge closer to information technologies (Engineering and Computer Science, Electronic Engineering, etc.), which enables the development of more technologies. This does not minimize the relevance of the results obtained and, much less, the validity of the methodology proposed and employed, only highlights the need for future research that, in the trail established here, seek to clarify the existing relationship between the variables.

Finally, it should be noted that the methodology developed in this article and the results obtained represent an initial effort, with the objective of stimulating the use of data made available by applications for the construction of more effective economic indicators. Therefore, this exploratory study fulfilled the function of directing the elaboration of new hypotheses around the factors that explain the innovation in applications, that is, the elements that sustain the quality differentials of demand. Moreover, the study also met the objective of presenting a higher quality indicator than that usually used for the statistical test of new hypotheses.

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