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Challenges for the measurement of Innovation Ecosystems and Entrepreneurial Ecosystems in Brazil

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Abstract

Purpose: This paper aims to identify metrics and indicators of innovation ecosystems and entrepreneurial ecosystems and to discuss the limitations of these metrics in the Brazilian case. **Theoretical framework**: From a theoretical point of view, the paper contributes to the analysis of the differences and similarities between the concepts of innovation ecosystems and entrepreneurial ecosystems. From a methodological perspective, the paper proposes indicators and metrics and points out the limitations for measuring entrepreneurial and innovative ecosystems in Brazil. **Design/methodology/approach**: The study's qualitative approach is based on a literature review, a documentary research, and data collection for the characterization of innovation ecosystems and entrepreneurial ecosystems. The paper identifies the main indicators and metrics, their data sources and the limitations of these indicators and metrics in the Brazilian case. **Findings**: It was observed that despite the existence of multiple data sources, the measurement of entrepreneurial ecosystems in Brazil entails constraints such as time lag of the data; voluntary filling of databases; lack of transparency at the regional level; and incomplete or skewed data. **Research, Practical & Social implications**: From a theoretical point of view, the paper contributes to the analysis of the differences and similarities between the concepts of innovation ecosystems and entrepreneurial ecosystems. From a methodological point of view, the study proposes indicators and metrics and points out the limitations for the measurement of entrepreneurial and innovative ecosystems in Brazil. **Originality/value:** When identifying limitations, the paper proposes alternatives to improve the measurement of innovation ecosystems and entrepreneurial ecosystems in the country and in its different regions. This is essential for designing and monitoring public policies to support innovation, especially those aimed to support entrepreneurs and small businesses.

Keywords: Entrepreneurial Ecosystems; Innovation Ecosystems; Metrics.

Resumo

Objetivo: Identificar métricas e indicadores de ecossistemas de inovação e de empreendedorismo, bem como discutir as limitações dessas métricas, no caso brasileiro. **Método**: abordagem qualitativa, baseada em revisão bibliográfica, pesquisa documental e levantamento de dados, com a finalidade de caracterizar ecossistemas de inovação e de empreendedorismo, identificando os principais indicadores e métricas, bem como as suas fontes de dados e limitações, no caso brasileiro. **Originalidade/Relevância**: Ao identificar as limitações, este artigo propõe alternativas para aprimorar a mensuração de ecossistemas de inovação e de empreendedorismo no país, em suas diferentes regiões, o que é fundamental à formulação e monitoramento de políticas públicas de apoio à inovação, sobretudo aquelas dirigidas a empreendedores e a pequenas empresas. **Resultados**: Verificou-se que, apesar da existência de múltiplas fontes de dados, a mensuração de ecossistemas de empreendedorismo no Brasil esbarra em limitações, como a defasagem temporal dos dados, o preenchimento voluntário das bases, a falta de transparência no nível regional, e informações incompletas ou enviesadas. **Contribuições teóricas/metodológicas**: Do ponto de vista teórico, este artigo contribui para a análise das diferenças e das semelhanças entre os conceitos de ecossistema de inovação e de empreendedorismo; e do ponto de vista metodológico, ele propõe indicadores e métricas, bem como aponta as limitações para a mensuração de ecossistemas empreendedores e inovadores no Brasil.

Palavras-chave: Ecossistemas de Empreendedorismo; Ecossistemas de Inovação; Métricas.

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INTRODUCTION

The literature on the role of entrepreneurs in economic development has suggested that interactions initiated through their activity can be analyzed and attributed to the concept of entrepreneurial ecosystems (Liguori et al., 2019; Neumeyer and Santos, 2018; Nicotra et al., 2017; O'Connor et al., 2018; Spigel and Harrison, 2017; Stam, 2018). Concurrently, the literature on innovation ecosystems has shown that their different dimensions require different metrics (Carayannis et al., 2018; Gomes et al., 2016; Jackson, 2011; Oh et al., 2016). It is possible to identify differences between the two concepts: while the concept of innovation ecosystems focuses on firms as innovation actors; the concept of entrepreneurial ecosystems augments the role of individual skills to innovate which are important features of entrepreneurial activity (Xu and Maas, 2019).

Despite being distinct, innovation ecosystems and entrepreneurship ecosystems should not be perceived as conflicting concepts, but as complementary to one another. In this sense, Xu and Maas (2019) list the common principles of the two approaches, which should orient public policies that aim to support entrepreneurship and innovation. These principles include: listening to local needs, because each context is unique (Isenberg, 2010); having a long-term vision, since ecosystems take time to develop (Feld, 2012); working collectively, involving the public and private sectors (Mason and Brown, 2014); acting responsively, i.e. considering the fact that ecosystems evolve over time (Isenberg, 2010); and sharing motivational stories, increasing the stakeholders' confidence (Mack and Mayer, 2016). Hence, according to the authors, the State can act both as a feeder and as a stakeholder of an ecosystem.

Based on the assumption that each context is unique, and that ecosystems take time to develop, it is essential to propose indicators and metrics of innovation and entrepreneurship that help design public policies to foster innovation activity, especially those directed to entrepreneurs and small businesses. In view of this, the aim of the present article is to list some of these indicators and metrics applied to the Brazilian case, as well as discuss their limitations. To this end, we bring a brief discussion on the concepts of innovation ecosystem and entrepreneurship ecosystem, pointing out their differences and complementarities. Then, possible indicators and metrics for both ecosystems will be set out, followed by the issues related to these metrics and indicators in the Brazilian context. Finally, in the last section, we present conclusions and topics for future research.

INNOVATION ECOSYSTEMS AND ENTREPRENEURIAL ECOSYSTEMS

Innovation ecosystems

The concept of innovation ecosystems, according to Xu and Maas (2019), involves the concept of innovation systems, proposed by Lundvall (1992), and the concept of national innovation systems, introduced by Freeman (1987). Based on the seminal works of these authors, several scholars associated with the evolutionary approach in Economics began to analyze the systems of innovation on local, regional, and national scales.

As observed by Nelson (2018), evolutionary authors may be differentiated from those of other currents of economic thought because, unlike the latter, they consider continuous change led by innovation to be the core of economic theory. Their main source consists of Schumpeter's works, which state that capitalism is characterized not by cycles of growth tending to equilibrium, but by cycles of change, interspersed with periods of relative stability.

Evolutionary authors often use analogies between the economic and biological systems in their analysis of the processes of change. For these authors, firms have resources that can be more or less adequate to the competitive process which results from their interaction with the market. The most successful firms tend to survive longer and replicate their practices through routines, just as organisms that are more able to survive in certain environments tend to stay alive longer and replicate their characteristics through genetic transmission mechanisms.

This analogy, however, should be used with caution. While biological evolution is a 'blind' process, determined by the interactions between organisms themselves (Dawkins, 2007), economic evolution is characterized by intentionality. Therefore

> A principal difference between economic evolution and biological evolution is that economic actors generally are able to choose what they are doing and how they are doing it, and have the capability to learn not only from their own experience but from available information about alternatives (Nelson, 2018, p. 7).

By proposing the concept of innovation systems, evolutionary authors draw attention to the importance of the context in which firms operate, and to the need to understand the learning processes that foster innovative activity.

In addition, the concept of innovation ecosystems reinforces the systemic aspect of the innovative activity of firms, emphasizing the coevolution among agents that characterizes this process (Xu and Maas, 2019). Innovation ecosystems is an adaptation of the concept of business ecosystems, proposed by Moore (1993), which entails that an innovation ecosystem is a model of the dynamics of economic interactions between agents that develop technology and innovations. The actors in this model are not only physical and human capital engaged in innovation, but also the institutions that take part in the ecosystem (Jackson, 2011).

Although there is no clear established distinction between the concepts of innovation ecosystems and entrepreneurship ecosystems –except for the aforementioned differences–, the subject has drawn growing interest, both from scholars and policymakers interested in innovative activity. Not by chance, the recapture of this concept refers to the article by Jackson (2011), who worked at the National Science Foundation. The diffusion of the paper among policymakers has brought about a discussion on how to design, build and operate a fruitful innovation ecosystem. Responses, however, are often elaborated based on a linear perspective of innovative activity, which contradicts the concept itself (Wallner and Menrad, 2011).

Thus, several authors consider that the basis of the concept of innovation ecosystem is weak (Oh et al., 2016; Gomes et al., 2016). In that regard, Oh et al. (2016) explain that, when considering the possibility of designing an ecosystem, some authors perform teleological analyses to identify the purpose of this ecosystem, which contradicts the idea that it is shaped by interactions. Thus, the biggest challenge lies precisely in the difficulty of establishing metrics capable of analyzing an innovation ecosystem.

To escape from the hazards related to the elaboration of the innovation ecosystem concept, which is still ongoing, it is relevant to increase comprehension regarding what the analysis of this phenomenon comprises. According to Oh et al. (2016),

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the distinctive features of recent studies about innovation ecosystems are: the explanation of the systemic character of innovative activity; recognition of the importance of information and communication technologies for the establishment of networks among the actors of the system; open innovation; actors of the system that are able to imitate; emphasis on the differentiated roles that organizations and firms occupy in the system and; the importance of market forces.

Jackson (2011) points out that, in the same ecosystem, two weakly related 'economies' (or economic subsystems) coexist: the research (academic) economy and the commercial (market) economy. To these subsystems, Wallner and Menrad (2011) add culture and establish a difference between innovation and innovative capacity: innovation is defined as the manifestation of innovative capacity, which, in turn, is strongly influenced by cultural traits. Examples of cultural traits that may be significant for innovative capacity are: Risk aversion; the perception of failure as a learning experience (and not as defeat); the willingness to share information and knowledge; and tolerance for the diversity of ideas and people.

Entrepreneurial ecosystems

The approach to entrepreneurial ecosystems (ESA) stems from the combination of recent research in areas such as entrepreneurship, economic geography, urban economy, and the economics of entrepreneurship. This approach seeks to investigate how urban and regional contexts affect ambitious entrepreneurship (Stam et al., 2016) (for more details see Baumol, 1990).

The concept of entrepreneurial environment (or ecosystems), which aims to explain the influence of social and economic aspects of regions on the entrepreneurial process, was developed in the seminal works of Pennings (1982), Dubini (1989), Van de Ven (1993), and Bahrami and Evans (1995). In summary, in the ESA, the context is relevant, unlike other approaches, in the ESA the entrepreneur and entrepreneurial activity are the focal point of analysis, not the firm. In this sense, research on entrepreneurial ecosystems (EE) is strongly focused on entrepreneurs and startups, not on larger and more established enterprises, nor on low-growth small and medium-sized enterprises.

In addition to the knowledge related to technical know-how, which is indispensable for the development new products and technologies and to the functioning of the market, the ESA emphasizes knowledge on the entrepreneurial process itself. This includes knowledge about the following aspects: the challenges that entrepreneurs face while developing their business; how to design business plans and pitches of ideas for angel investors and venture capitalists; and how to overcome the issue of lack of experience when working with potential customers and suppliers. Hence, mentoring and networking are crucial elements for sharing knowledge within an ecosystem (Lafuente et al., 2007).

It is worth noting that, unlike other concepts (such as industrial districts, clusters, learning regions and regional innovation systems), the ESA does not see entrepreneurship only as a result of the system: it also considers the importance of entrepreneurs as central players (leaders) in the creation of the system and in maintaining its vitality (Feldman, 2014). This conception entails, therefore, reduced government participation, which is seen more as a feeder of the ecosystem than as a leader (Feld, 2012).

Based on the various contributions found in the literature, Mason and Brown (2014, p.5) summarize the definition of an EE as follows:

> A set of interconnected entrepreneurial actors (both potential and existing), entrepreneurial organizations (e.g. firms, venture capitalists, business angels, banks), institutions (universities, public sector agencies, financial bodies) and entrepreneurial processes (e.g. the business birth rate, numbers of high growth firms, levels of 'blockbuster entrepreneurship', number of serial entrepreneurs, degree of sellout mentality within firms and levels of entrepreneurial ambition) which formally and informally coalesce to connect, mediate and govern the performance within the local entrepreneurial environment.

Compatible with this perspective is Isenberg's contribution (2010), in which it is stated that public managers who seek to foster an EE in their region should emphasize the role of local conditions, bottom-up processes, and ambitious entrepreneurship. in other words, they are to favor high-impact entrepreneurs and focus on institutions, especially in stimulating the formation of entrepreneurial culture and establishing a legal, bureaucratic, and regulatory framework conducive to the development of entrepreneurship. Based on this perspective, the author identified six distinct domains within an entrepreneurship ecosystem: (1) appropriate culture, (2) public support policies, (3) appropriate funding available, (4) quality of human capital, (5) open markets, and (6) a set of support institutions.

Stam and Spigel (2016), in turn, divide the elements of an entrepreneurship ecosystem into two categories: (1) framework conditions, which include: social conditions (formal and formal institutions) and physical conditions that stimulate and restrict human interaction; and (2) systemic conditions that are at the heart of the ecosystem (networks of entrepreneurs, leadership, funding, talents, knowledge services and support services). The presence of these elements and the interaction between them are critical for the success of the ecosystem. Table 1 highlights the main similarities and differences between entrepreneurial ecosystems and innovation ecosystems approaches.

	Entrepreneurial Ecosystems (EE)	Innovation Ecosystems (IE)
Main unit of analysis	Entrepreneur (individual level) – focus on individual agency and not on the human-made context	Organization (firm level) – focus on dynamic capabilities of firms as the main determinants of capitalist change
Institutional context	Both approaches have a systemic perspective, emphasize the importance of the institutional context, and highlight the external forces that influence economic actors.	
	EE gives more emphasis to formal institutions	IE presents a balanced perspective between formal institutions (laws, regulations) and informal institutions (social codes, cultural patterns) and puts more emphasis on historical trajectories and political context
Role of the state	The state has a marginal role as feeder of the ecosystem that helps to set the best structure of incentives	The state has a complementary but also active role, leading in the context of high-risk activities and major technological change

Tab. 01
Main similarities and differences between the approaches to innovation ecosystems (EI) and Entrepreneurship (EE)
Source: The authors.

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METRICS AND INDICATORS FOR THE CHARACTERIZATION OF INNOVATION AND ENTREPRENEURSHIP ECOSYSTEMS

Firstly, it is important to mention that we understand metrics as quantitative measures of performance, constructed from data, indicators, and surveys. The importance of metrics is summarized by Farris et al., (2015, p. 13):

> A metric is a measuring system that quantifies a trend, dynamic, or characteristic. In virtually all disciplines, practitioners use metrics to explain phenomena, diagnose causes, share findings, and project the results of future events. Throughout the worlds of science, business, and government, metrics encourage rigor and objectivity. They make it possible to compare observations across regions and time periods. They facilitate understanding and collaboration.

As pointed out in the previous section, there are similarities and differences between the approaches of innovation ecosystems and entrepreneurial ecosystems. This is also possible to observe when it comes to the indicators and metrics proposed to measure these ecosystems: some are specific and are applied only in one of the modalities, while others can be used in both ecosystems. Next will bring further discussion on this topic.

Innovation ecosystems

Regarding innovation ecosystems (IE), there are indicators and metrics at the national and regional level. At the national level, there are several indicators and quantitative metrics consolidated in the literature, including: remuneration of the workforce with higher education; number of workers with MSc and PhD titles per 100,000 inhabitants; research and development (R&D) expenditure as a percentage of GDP, number of licenses, patents and high-growth enterprises, share of venture capital in financing technology-based enterprises, among others. In addition, there are official indicators and metrics included in sample surveys, which identify: the innovative capacity of several industrial sectors of a given country; investments in innovation; the share of enterprises with established cooperation networks, and other relevant pieces of information. Moreover, investments in science and technology, both public and private, are considered a proxy of the generation of new knowledge, which flows in innovation ecosystems (Stam, 2018).

Regional scientific competences, in turn, can be mapped through the identification of scientific and technological institutions (ICTs) present in the territory, as well as research groups and their respective fields (Nicotra et al., 2017). The identification of networks established between research groups and firms is also a possible metric of innovative capacity of regions or countries (Urti, 2017).

It is also worth mentioning that the complexity of products is defined by the amount of productive knowledge in a given economy, considering its use and its continuous improvement. This concept represents another possible metric of the innovation capacity of firms, for it refers to the company's ability to develop knowledge-intensive products and, consequently, to form markets and networks for these products where the knowledge produced can be absorbed. This concept also assumes that collective knowledge does not depend exclusively on individual knowledge, but on the combination of different types of knowledge originated in a society that creates new products through complex networks of interaction.

According to Hausmann et al., (2013), products are vehicles for knowledge. The concept of complexity proposed by these authors, originally conceived for measurements at the national level, can also be applied to cities, regions and states in the same country, thus being a viable metric for innovation ecosystems, since it allows the measuring of knowledge interaction networks and knowledge flows present in ecosystems. The complexity indicator is obtained by applying the methodology of the product space developed by the authors, in which the exported products are grouped into networks, differentiated by sectors and displayed in a graph in which different colors correspond to the level of complexity of each product. In this sense, the product space:

> allows us to understand, based on countries' export agenda, the productive knowledge each nation has. These skills or abilities comprise several factors, such as: capital, work, technology, institutions, infrastructure, social relations, among others. The more productive knowledge a given locality has, the greater the number of products it can produce and export, and the more complex these products will be (Data Viva, 2019, [s. p]).

A complementary metric to the previous one is the entropy indicator, which illustrates the diversity or the sectoral variety of a country or a region. The concept of entropy first emerged in the field of Physics, in studies dedicated to thermodynamics, later becoming a metric for complex systems in Economics (Furtado et al., 2015). In Vieira (2013), entropy is presented as a measure of heterogeneity, that is, the greater the heterogeneity, the more intense the transformation of a system; therefore, the greater the entropy, the greater the complexity of a phenomenon.

In the area of geography of innovation, this metric has also been used to measure sectoral variety and its impact on regions and on innovation; and, more specifically, to understand the concept of related variety (Boschma and Iammarino, 2009; Castaldi et al., 2015; Frenken et al., 2007), defined as the set of sectors that share proximity in terms of skills (Frenken, 2006).

According to Frenken et al. (2007), the concept of related variety expresses the idea that some sectors are more related than others and, therefore, generate relatively more Jacobs externalities (i.e., economic benefits related to the diversification of productive activities in a city or region) than unrelated sectors. The degree of entropy is used to examine empirically the effects of related or unrelated variety in a region and in its industrial sectors.

The main advantage and the reason for using the entropy indicator is the context of diversification, for this indicator can be decomposed at each sectoral level, which increases comprehension of related variety (at the five-digit level) and unrelated variety (at the two-digit level of the classification of economic activities) (Frenken et al., 2007). The main advantage of the economic complexity indicator is the use of a more sophisticated methodology in the field of network studies. These indicators can then complement each other in order to portray productive structure in different places.

Additionally, there are also metrics of knowledge bases, calculated based on the statistics of employment data, which provide information on the qualification and sectoral profile of the workforce of a given region (Santos, 2016; Santos and Marcellino, 2016). According to Asheim et al. (2011), there are three knowledge bases: a (1) analytical, formed by the set of intensive activities in research and development; (2) synthetic, which involves activities related to the solution of concrete problems of the industry; and (3) symbolic, related to creative activities.

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Entrepreneurial ecosystems

As previously mentioned, the entrepreneurial ecosystems (EE) approach emphasizes institutional factors. Thus, the metrics related to the institutional environment for businesses are used to compare ecosystems in different countries. The metrics include corporate governance practices; corruption perceptions index; economic and/or commercial freedom index and index of regulatory quality. Kshetri (2014) also makes use of qualitative indicators in the analysis of the institutional environment, which include: speeches by political leaders, press releases of large corporations, policies to encourage the opening of businesses, investment laws, conditions for bankruptcy protection and financial markets, and changes in social norms and values linked to entrepreneurship.

While there is enough data for the mapping of the institutional environment, the metrics on individual traits of entrepreneurs, capable of affecting entrepreneurial activity at the local level (Audrestch and Belitski, 2017), remains insufficient. In an attempt to solve this problem and measure the relationships between organizations that provide support, firms and individuals, Cowell et al. (2018) used qualitative data extracted from interviews and focal groups featuring entrepreneurs. The authors also analyzed networks mapped from interactions, identified during research about the resources that entrepreneurs use, and in Twitter's database.

Credit et al. (2018) wrote a state-of-the-art paper on entrepreneurial ecosystem metrics and noted that most studies use primary data due to a lack of secondary data on entrepreneurship in general. They identified the most used data sources which are: Eurostat, a platform that gathers official statistics from the European Union and its members; the Global Entrepreneurship Monitor, a not-for-profit organization that conducts studies on entrepreneurship rates in several countries; Crunchbase, a database of innovative enterprises, financing and procurement; and InfoDev Database, an initiative supported by the World Bank, and linked to the infoDev Program initiative, which fosters a global network of incubators and innovation hubs related to environmental, agribusiness and digital entrepreneurship technologies.

Despite the shortcomings mentioned above, consistent growth of publications about entrepreneurship ecosystems has been observed since 2009. Such publications used mainly the following indicators and metrics: number of startups (Audrestch and Belitski, 2017); rates of entrepreneurship, of innovative entrepreneurship and of high-growth entrepreneurship (Bruns et al., 2017); number of industries represented by startups and data on individual startups (Nylund and Cohen, 2017); incubated firms in global incubator networks and participants in innovation hubs on climate technologies, agribusiness and digital entrepreneurs (Fernández-Fernández et al., 2015).

Credit et al. (2018) also noted that the World Economic Forum developed metrics to analyze entrepreneurship ecosystems, based on Isenberg's work (2010); however, these measures were applied to the national level, failing to consider local perspective and its related social and cultural characteristics.

Indicators and metrics for innovation ecosystems and entrepreneurial ecosystems

As formerly mentioned, there are specific indicators and metrics which can be used to analyze innovation and entrepreneurial ecosystems. In this sense, we highlight research on mechanisms for generating innovative enterprises, among which are the intermediaries (or brokers) of innovation, whose roles are fundamental in an ecosystem of innovation. According to Sapsed et al. (2007) intermediaries are important to the extent that they act as bridging institutions, capable of connecting the different local actors linked to innovation. Notwithstanding, these intermediaries also stimulate entrepreneurship. In fact, the mechanisms for generating innovative enterprises (Aranha, 2016) that include business incubators, technology parks, accelerators and coworking spaces are essential elements not only to encourage interaction between the knowledge infrastructure and the productive sector within the framework of an innovation ecosystem, but also to promote entrepreneurial culture, strengthening the entrepreneurial ecosystem. Thus, the mapping of these mechanisms, including the identification of the enterprises that are founded through them and the networks in which they are inserted, is a relevant indicator of the ecosystem support structure.

The country's culture concerning innovation and entrepreneurship, that is, the set of perceptions of the inhabitants of a country about these activities, is of fundamental importance to analyze both innovation ecosystems and entrepreneurship ecosystems. Such perceptions, in particular, can be measured by the diagnosis of individuals' risk aversion, of how failure is considered, and whether there is tolerance for different ideas and people (Wallner and Menrad, 2011).

A possible metric for risk aversion is the number of firms that resort to credit operations, in relation to the total number of firms in the region. In countries such as Brazil, for example, where there is high risk aversion, most small firms prefer to operate with their own resources instead of getting loans.

The ratio between the number of enterprises opened and enterprises closed, and the number of enterprises that an entrepreneur opens in a certain period, can be used as metrics for the perception of failure, since in societies where business failure is highly associated with personal failure, entrepreneurs tend to open fewer enterprises.

Tolerance for diversity, in turn, can be measured by the number of exchanging programs that exist in the universities and technical schools that incorporate an innovation ecosystem; by the percentage of foreign students in the total number of students of technical schools and universities; and by the percentage of immigrants in the total number of inhabitants of a region.

Finally, to monitor the evolution of entrepreneurial and innovation ecosystems some metrics regarding innovation outputs should be included. One example is the presence of high-growth firms (Stam, 2018), that is, firms with an average employee growth of at least 20% per year for a period of three years, and with ten or more people employed during the initial year of observation (IBGE , 2018) in the ecosystems.

In the same vein, the mapping of startups that were created and survived also constitutes a satisfactory indicator of an ecosystem (Nicotra et al., 2017). Startups are defined as technology-based firms, which seek to develop an innovative product/service, through an easily replicated business model with the possibility of scaling up, without proportional increase in their costs (ABStartups, 2018).

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MEASURING INNOVATION ECOSYSTEMS AND ENTREPRENEURIAL ECOSYSTEMS IN BRAZIL

This section aims to present the main data sources for the indicators and metrics mentioned previously available in Brazil, as well as their limitations.

Main data sources

The data provided by the official publications of the Brazilian Ministry of Science, Technology and Innovations (MCTIC), by the Brazilian Institute of Geography and Statistics (IBGE), by the IBGE´s Technological Innovation Survey (PINTEC), and by the Lattes Platform of the National Council for Scientific and Technological Development (CNPq), can be used to build the indicators and metrics mentioned previously.

The data made available at the abovementioned databases facilitates a comprehensive assessment of innovation and entrepreneurial ecosystems. The data provided by the PINTEC platform make it possible to assess firms' research and development expenditure and innovation expenditure; local scientific production can be mapped with the data available on the Lattes Platform and on the Brazilian Digital Library of Thesis and Dissertations, operated by the Brazilian Institute of Science and Technology; the ratio of workers with M.Sc and Ph.D titles per 100,000 inhabitants can be obtained with the data made available on the Lattes platform.

The PINTEC data can also be used to verify the ratio of researchers with graduate degrees that are full-time employees in internal R&D activities at enterprises that have implemented innovations in each state of the country. It is possible to map the cooperation networks between universities and enterprises in the country by using the data on research groups and curricula of the research group members, both available on the Lattes Platform (Urti, 2017). In addition, the Brazilian National Institute for Intellectual Property's (INPI) database provides information on patents granted in Brazil and/or overseas.

Information, data, visualizations and the indicator of economic complexity, at the local, regional, state and national levels, can be found on the Data Viva platform (http://dataviva.info/pt/). This platform was created by the government of the Brazilian state of Minas Gerais, through the Minas Gerais Agency for Promotion of Investment and Foreign Trade (INDI), with support from the Research Foundation of the State of Minas Gerais (Fapemig), in partnership with the MIT Media Lab. The calculation of entropy, in turn, can be made with the data from the statistics of economic activity, which, in Brazil, are included in the Annual Report of Social Information (Rais). The Rais also provides data on higher-level jobs in economic activities that constitute various knowledge bases (see Marcellino & Santos, 2016).

Regarding the data on finance, in Brazil, the survey of equity committed in venture capital is carried out by universities (FGV), consulting firms (KPMG) and banks (BNDES), but only at the national level (BNDES, 2017). The mapping of angel investors can be done with the help of the Anjos do Brasil network, which has regional centers in nine states (Anjos do Brasil, 2019).

The volume and types of investment in innovation made by the National Bank for Economic and Social Development (BNDES), by the Agency for Financing Studies and Projects (FINEP), and by the Brazilian National Research Council (CNPq), all federal agencies, can be accessed through the transparency portals of each agency. Through these portals, it is possible to verify the investments in the state and municipality levels. As to regional agencies, such as the regional Foundations for Research Support (FAP) and other funding agencies, the provision of data on resources invested in innovation depends on the existence of a transparency mechanism, which is specific for each agency.

Data on the mechanisms for generating innovative enterprises can be found at the website of the Brazilian National Association of Entities Promoting Innovative Enterprises (http://anprotec.org.br/site/sobre/associados-anprotec/). At the regional level, there are networks of these entities in some states of the country which provide information of their members on their websites. The centers of technological innovation and the technology transfer offices, located at the Institutions of Science and Technology (ICTs), are also relevant intermediaries.

The PINTEC also offers an overview of the innovative performance of enterprises at the regional level. The mapping of high growth enterprises (EAC in Portuguese) that allows assessing the evolution of the number of EAC in different states is carried out by the IBGE annually and published along with other entrepreneurship related statistics (the last edition is dated 2015).

Regarding the data on startups, it is worth mentioning the survey conducted by the Brazilian Association of Startups (ABStartups). This association, together with Accenture, presented an "x-ray" of the Brazilian startup ecosystem in 2017. The study was conducted through an open online questionnaire, which had the participation of over 1,000 Brazilian startups.

The study mapped a significant number of characteristics and obstacles. It also calculated the density index of these startups (index obtained by calculating [number of responding startups] / [number of skills per state or city], according to the estimated Brazilian population data provided by the IBGE, 2017), by state and city, as well as the efficiency index in the generation of startups (index obtained by calculating [GDP by city or state] / [number of responding startups], according to the GDP data, provided by the IBGE, 2015), at the state and municipal levels (ABStartups, 2018). The continuity of this survey and the consolidation of its methodology can serve as important metrics for the characterization of innovation and entrepreneurship ecosystems in the country.

Other sources of information about startups include: the Global Entrepreneurship Monitor, a non-for-profit organization that partners with Sebrae, the Brazilian agency for support of small businesses, to make available the data related to Brazil; information from the World Bank's InfoDev Program, cited by Credit et al. (2018), which cover some entrepreneurial activities; and data regarding Brazilian cities, provided by Crunchbase.

In 2019, Sebrae/MG, launched the Sebrae Local Development Index (Isdel). The core element this index observes is economic development, and its subdimensions are entrepreneurial capital, business environment, governance for development, productive organization, and competitive insertion – all available on the institution's website, by state and by municipality. It is worth mentioning that the subdimensions 'entrepreneurial capital' and 'productive organization' are particularly relevant for the characterization of entrepreneurship and innovation ecosystems

Finally, the data on the Brazilian institutional environment can be found in the statistics of international and national organizations, such as the Heritage Foundation, Transparency International and the Brazilian Institute of Corporate Governance (IBGC).

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Limitations of data sources and of some indicators and metrics

The limitations of data sources vary according to the database. The Lattes Platform is fed voluntarily, therefore it may be incomplete; and data on the volume and percentage of public and private investment in R&D are made available by MCTIC only at the national level, undermining analyses at a subnational scale.

The main limitation of the PINTEC is the sample used, that includes only enterprises with more than ten employees and, mostly, enterprises operating in the industrial sector, which hinders a throughout analysis.

The IBGE´s indicator of high-growth enterprises is also limited, as it may portray enterprises that in fact are not innovative. To observe innovative enterprises, it would be necessary to identify them combining data from the EAC and the PINTEC surveys. However, this information is not available in official databases.

Regarding the data on investments and patents, they can be easily found, but only at the federal level. Regional agencies have difficulties to provide data due to their fragilities or even to the lack of access to investment data. There are also limits to the information from the ICTs innovation offices, which is not readily provided.

Regarding the infoDev website, a research about Brazil provided only specific information about programs to support family farming, incubators, and digital entrepreneurs. In addition, it is difficult to use data provided by international organizations on the Brazilian institutional environment, given the availability restraints when it comes to the information on how these indexes were constructed.

Regarding the Isdel website, despite all relevant indicators that characterize the ecosystems and their corresponding methodological notes which are available online, it is not clear whether the calculation of these indicators will continue to be carried out. This limits their use, because metrics only make sense if there is the possibility of constructing time series, which help guide the design and the monitoring of public policies.

In addition to data limitations, there are specific difficulties observed for some indicators and metrics, such as the entropy indicator, based on the industry standard classification, which reduces its explanatory power over the connections between sectors (Neffke et al., 2011). Other limitations associated with this indicator involve information on formal industrial occupations, patents, production, export and import data, which constitute obstacles to the metric of economic complexity. This is due to the fact that international trade data are not able to accurately reflect how much knowledge a given place has accumulated, as demonstrated by research on global chains. Moreover, the emphasis on industry is limiting, as it leaves out a large amount of economic activities that are responsible for a great deal of knowledge production.

Considering the mapping of mechanisms for generating innovative enterprises, the first was carried out by MCTIC in 2019, and there is no information on a possible replication of the study in the short term. In addition, while Aranha (2016) includes technology parks and coworking spaces in its definition of innovative enterprise generation mechanisms, MCTIC has mapped only incubators, accelerators, and open laboratories.

FINAL REMARKS

The characterization, measurement and analysis of the evolution of innovation and entrepreneurship ecosystems are not simple tasks, since there is still no consensus on the definition of these concepts and on their dimensions, which are necessary to elaborate indicators and metrics in many cases.

As explained in the previous sections, measuring ecosystems in Brazil is not trivial, since the constraints include many obstacles related to both data sources and the availability of these sources. Table 2 summarizes the indicators and metrics of innovation and entrepreneurship ecosystems, their corresponding data sources, and the main limitations identified.

Regarding the data made available by official sources, there are some obstacles to the construction of indicators and metrics such as: (1) the time lag between data collection and availability; (2) data sources that are fed voluntarily which may lead to underreporting of information; (3) outdated data, due to surveys conducted with large time intervals, for instance, the Population Census, or recent surveys, such as the CNPq Census of Research Groups; (4) lack of transparency at the regional level, i.e. data that depend on transparency mechanisms or compilation by regional agencies; (5) data available only at the national level; and (6) incomplete or biased data at the regional level, due to the nature of the survey, as verified in the case of the PINTEC.

Difficulties also comprise the construction of indicators that depend on data release from official sources that are not easily available or are even non-existent. In this case, the problems arise initially from the need to collect data from primary sources and, subsequently, from the structuring of this information. At the regional level, this work can be performed by statistical foundations; however, many states do not have these institutions and/or lack the necessary resources.

Another obstacle that is worth mentioning is the fact that some data are very recent and, therefore, dependent on surveys by class associations.

Researchers and entrepreneurs interested in structured and well-defined information will have to gather efforts to pursue their objectives, using different metrics and databases, as well as understanding the context of the territory, considering 'approximate' results. In this sense, our paper contributes to the compilation of the main metrics to be applied.

As possible solutions to the limitations that were found, we can mention: (1) the need to invest in data mining, big data and artificial intelligence tools, in order to facilitate the collection of information by the institutions responsible for developing statistics and supporting innovation, thus escaping the limits imposed by the time lag of traditional data collection; (2) the strengthening of regional agencies to support innovation through the training of their employees in the identification of indicators and in the elaboration of metrics, which would make them able to assist these agencies in the planning and execution of development actions; and (3) the articulation of the different national institutions involved in the elaboration of these metrics and indicators, so as to avoid the repetition of efforts and to integrate the collected pieces of information.

All these actions, however, do not seem attainable in the short term, in view of the dismantling of the current public structure to support science, technology and innovation in Brazil. Due to space limitations, we will not develop the analysis of challenges related to institutional structure, which represents a relevant topic for future research. Finally, it is important to highlight the

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Data source	Ecosystems	Description	Level of analysis	Indicator/Metric	Limitations
IBGE	Innovation and entrepreneurial ecosystems	Entrepreneurship statistics	National	Proportion of the high growth of enterprises in the total number of enterprises; number and types of high-growth enterprises.	Not all high-growth enterprises are innovative
MCTIC	Innovation and entrepreneurial ecosystems	Mapping of mechanisms for generating innovative enterprises	National and state	Number of incubators, accelerators, and open laboratories.	It is not clear whether this mapping will continue to be carried out and it does not cover all mechanisms
Sebrae MG	Innovation and entrepreneurial ecosystems	Local development index	National, state, and local	Subdimensions 'entrepreneurial capital' and 'productive organization'.	It is not clear whether the calculation of indexes will continue to be carried out.
PINTEC	Innovation ecosystems	Statistics	National	Proportion of innovative enterprises in the total number of enterprises; Innovation networks and R&D expenditure of innovative enterprises	Limitations related to the sample
MCTIC	Innovation ecosystems	Data on R&D expenses	National	Share of R&D expenses in GDP and growth of R&D expenditure.	No data is made available at the state and local levels
FINEP	Innovation ecosystems	Innovation map and reports of FNDCT	National	Enterprises and research institutions supported by the FINEP over the last years, grouped by sector, and reports on financing innovation.	Does not apply
BNDES	Innovation ecosystems	Data on innovation support programs	National	Numbers of startups and innovative enterprises financed by the Bank.	Does not apply
Rais	Innovation ecosystems	Data on higher-level jobs in economic activities	National, state, and local	Indicator of entropy* and proportion of workforce hired in R&D activities	Limitations to explain the connections between sectors.
INPI	Innovation ecosystems	Patent data	National	Patents granted, triadic patents per million inhabitants.	No data is made available at the state and local levels
Transparency International	Entrepreneurial ecosystems	Data on corruption	International	Corruption rank in different countries.	Lack of information on methodology
Sebrae	Entrepreneurial ecosystem	Entrepreneurship rates and GEM data	International	Opportunity indicator, capacity indicator, failure era, entrepreneurial intentions, early entrepreneurship, motivational index, job creation estimation	No data is made available at the state and local levels
InfoDev	Entrepreneurial ecosystem	Entrepreneurial activities	International	Series of trade, investment, innovation, economic and sectorial indicators.	Little information made available on Brazil. .
Heritage Foundation	Entrepreneurial ecosystem	Institutional environment	International	Economic freedom index	Lack of information on methodology.
Crunchbase	Entrepreneurial ecosystem	Data on innovative enterprises	International	Startups: investment, financing, acquisitions, and market.	Little information made available on Brazil.

Tab. 02
Summary of the data related to indicators and metrics of innovation and entrepreneurial ecosystems in Brazil
Note: (*) The indicator can be calculated from the Rais datum; however, it is not made available by official sources.
Fonte: Os autores.

importance of jointly analyzing the metrics of innovation and entrepreneurship, thus contributing consistently to the analysis of innovative and entrepreneurial activity in Brazil.

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Conflit of interest statement

The authors hereby confirm that there are no competing interests to declare.

Authors' statement of individual contributions

Roles	Authors Contributions		
	Rovere, RLL	Santos, GO	Vasconcellos, BLX
Conceptualization	X	X	X
Methodology	X	X	-
Software	-	-	-
Validation	X	X	-
Formal analysis	-	-	-
Investigation	X	X	X
Resources	-	-	-
Data Curation	X	X	-
Writing - Original Draft	X	X	X
Writing - Review & Editing	-	X	-
Visualization	X	X	-
Supervision	X	-	-
Project administration	-	-	-
Funding acquisition	-	-	-

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