Disponível em
http://www.desafioonline.ufms.br
Desafio Online, Campo Grande, v.9, n.1, Jan./Abr. 2021

ECONOMIC COMPLEXITY: A SYSTEMATIC REVIEW OF LITERATURE

COMPLEXIDADE ECONÔMICA: UMA REVISÃO SISTEMÁTICA DA LITERATURA

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Abstract

This is a systematic review of the literature on economic complexity. We organize the most current and relevant research studies on the construction of the Economic Complexity Index and its empirical analysis. We searched "Economic Complexity" and its relative direct equivalent term "Economic Complexity Index", "Economic Growth", "Economic Development". The initial selection of the studies found 29 articles in a universe of 472. A total of 44 papers were obtained from Science Direct, 185 from Web of Science and 243 from Scopus. An important fact found in the review is that, since the more traditional empirical literature on the subject is still nascent, its application to regional realities is still nascent. This can be identified by the fact that in a significant universe of studies, only 5 presented proposals for methodological adaptation to the regional scope. In the literature, it is usually concluded that the productive structure of a country or region directly influences the level of growth, and high-income level is related to high complexity.

Keywords: Complexity; bibliometrics; growth

Peer Review under the responsibility of Escola de Administração e Negócios da Universidade Federal do Mato Grosso do Sul ESAN/UFMS.

Resumo

Esta é uma revisão sistemática da literatura sobre complexidade econômica. Organizamos as pesquisas mais atuais e relevantes sobre a construção do Índice de Complexidade Econômico e sua análise empírica. Pesquisamos "Complexidade Econômica" e seu termo equivalente direto equivalente "Índice de Complexidade Econômica", "Crescimento Econômico", "Desenvolvimento Econômico". A seleção inicial dos estudos encontrou 29 artigos em um universo de 472. Foram obtidos 44 artigos no Science Direct, 185 no Web of Science e 243 no Scopus. Um fato importante encontrado na revisão é que, como a literatura empírica mais tradicional sobre o assunto ainda é incipiente, sua aplicação às realidades regionais ainda é incipiente. Isso pode ser identificado pelo fato de que, em um universo significativo de estudos, apenas 5 apresentaram propostas de adaptação metodológica ao âmbito regional. Na literatura, geralmente conclui-se que a estrutura produtiva de um país ou região influencia diretamente o nível de crescimento, e o alto nível de renda está relacionado à alta complexidade.

Palavras-chave: Complexidade; bibliometria; crescimento

1. Introduction

Economic complexity has been studied as a way to understand economic growth pathways. By measuring a region that has economic complexity, as well as product sophistication, we can highlight the most important features for the development of economies and give cohesive signals for making efficient economic policies.

This paper tries to organize the most current and relevant research on the methods and techniques of construction of the Economic Complexity Index (ECI) and its empirical analysis. In order to map as best as possible, the empirical literature on the issues of economic complexity, this paper conducts a systematic literature review, in the formats proposed by Kitchenham (2004), with minor adaptations. Systematic review (SR) is a way to identify, evaluate and interpret all relevant research available related to a research question, topic or phenomenon of interest (Kitchenham, 2004).

In contrast to the conventional literature review, SR follows a strict and well-defined sequence of methodological steps, which ensures a high scientific value to the results, so that the main reason for using such a review format is to increase the probability of identifying more

accurate results on the topic of interest when compared to a less formal review format (Pedreira & Piattini & Luaces & Brisaboa, 2007).

This process is summarized in a report composed of three main steps: planning, conducting and reporting results. The first step consists in determining the needs of the review and designing a protocol that contains information (such as keywords, inclusion and exclusion criteria) to support the whole systematic review process. In the conduction stage, all the bibliography that conforms to the pre-established protocol is collected; the most important studies are evaluated and selected, and the most important information is extracted from them. Finally, results are reported to the academic community (Kitchenham, 2004).

Therefore, this article intends to conduct an SR so as to bring out the main empirical work found in the most relevant databases on the relationship between economic complexity and economic growth. It is worth mentioning that the bibliographic searches were performed during the months of November and December 2018. The computer tool Start 2.3.4 was used as an apparatus for conducting the systematic review. This review was conducted in three main stages, each with its own detailed rules. This section presents the decisions made in each part of this SR, as well as the data collected, with small adaptations. There, we expect to contribute to the regional science literature with this review by helping other academics to shed light on this topic. The paper follows with the Planning section, the method for conducting the review, the data and results.

2. Planning

In the planning stage, the research protocol was designed so as to provide the necessary guidelines for any decision-making in the SR driving process. Thus, the following items are described below:

Objective: to organize the most current and relevant research on the methods and techniques of construction of the economic complexity index and its empirical analysis.

Revision Issues: SR is intended to provide material that can answer to particular, unanswered questions in an organized manner. We considered some questions for the present review:

1. What has already been published about methods of calculation and application of the economic complexity index (ECI)?

2. What has already been published about regional or municipal application of the economic complexity index?
3. How is the economic complexity index analyzed?

In an attempt to answer such questions, an exploratory analysis was conducted on *Google Scholar* to identify some suitable reference sources for extraction of a set of keywords to be used in SR. Based on the questions that support the review and the works collected for the exploratory analysis, the following keywords were used: “Economic Complexity”, “Economic Growth”, “Economic Development” and “Economic Complexity Index”.

Population (represents the specification of the set of studies to be observed): scientific articles available online that propose methods and techniques of composition of the Economic Complexity Index and/or are related to economic growth.

Intervention (represents what should be observed in the articles): methods and techniques of ECI construction; empirical analysis of the economic growth level; level of geographical analysis (regional or international) and nature of the data used for ECI as well as for the growth model.

Sources of Selection: After checking which databases contained the most suitable set of texts for the research, according to the articles obtained from the exploratory analysis, we detected the databases *Science Direct*, *Web of Science* and *Scopus*. It should be mentioned that other platforms were considered; however, the mechanisms offered for retrieval of information from the articles were not convenient because a large number of results was obtained.

Search Method: We searched through sets of keyword combinations (search strings). The terms that were found were used to perform searches in these sets - preferably in the title, abstract or keywords of the article. Importantly, the databases used in the revision have specific search engines; therefore, adaptations were necessary. Each source was submitted to two similar search strings, one with a more general purpose and another with the objective of finding more specific studies. This will be demonstrated in the conduction stage.

Another important information is that even before the search was performed, in all databases, date and language filters were applied. For the first filter, we considered publications from the year 2006 to the year 2018. We believe that a 12-year span is recent enough so that it can cover up-to-date discussions as well as show a historical evolution in the production of knowledge in the field. For the second filter, the search was performed using strings in English because it has greater international reach. Even when the full text of relevant studies are not originally in English, at least they include a summary and keywords in that language.

Criteria for Selection of Studies: Some inclusion (I) and exclusion (E) criteria were defined for the purposes of article selection. Thus, we determined that, even when an article had one or more inclusion criteria, the presence of at least one exclusion criterion would already be sufficient for not adding this article into the information extraction group. The criteria were defined as follows:

- (I-1) The study presents methods and/or techniques for the construction of ECI.
- (I-2) The study presents empirical analysis on complexity and/or its relation to economic growth.
- (I-3) The study presents an analysis of the degree of economic complexity at the regional level.
- (E-1) The study makes only theoretical reflections on the themes of economic complexity.
- (E-2) The full text is not written in Portuguese, English or Spanish.

Initial Selection of Works: as mentioned above, the first practical step is the design of the strings and their submission to the search engine of the selected databases. All results are selected and their information is extracted into BibTeX format files. It is through the Start tool that such information is organized, made available for reading and interpreted by the researcher. Thus, the initial selection is the stage at which the review author identifies the relevance of the works by reading the title, abstract and keywords, and then chooses them according to the adequacy to the protocol and, specifically, considering the selection criteria. It should be mentioned that the initial selection of works is a preliminary stage, and the selection criteria can also be applied in the later stages.

Data Extraction: After the initial selection, all included jobs were filtered again. The reviewer now reads the full articles and extracts the necessary information as set out in the protocol. The data extracted for the present review are:

1. Geographic Level of the Study - were the variables used at regional or international level?
2. Nature of the data processed - what were and how were the study variables constructed and / or extracted?
3. Method of Construction of the Economic Complexity Index - what is the proposal for obtaining the ECI?
4. Complexity Application / Validation Model - what are the characteristics of the quantitative model to understand the sophistication of the economy?
5. Results and authors' conclusions.

Therefore, once the protocol has been drafted, the review moves to the conducting step.

3. Conducting The Review

The first step of this stage is to search the databases determined in the protocol (Science Direct, Web of Science and Scopus) using the strings:

1. "Economic Complexity" OR "Economic Complexity Index"; and,
2. ("Economic Complexity" OR "Economic Complexity Index") AND ("Economic Growth" OR "Economic Development".

The presence of quotation marks in strings has the effect of fetching the internal terms completely rather than scattered throughout the title, abstract, or keywords. However, the Boolean operator "OR" wants to find one or other of the terms in parentheses (because of the similarity of the terms) and the "AND" operator is added to necessarily find the set of terms on its right and its left.

In the search, 472 studies were retrieved, with 185 duplicates (because the same article was found in more than one database). After the exclusion of duplicate papers, 258 out of the remaining 287 articles were rejected at the initial selection stage (because they did not fit the objectives of the review) and 29 papers were accepted. Articles should necessarily be available online in full text for reading and extraction of data. Regarding the databases, 44 texts were obtained in Science Direct, 185 in Web of Science and 243 in Scopus.

After the initial selection stage, in which the papers are included or excluded from the analysis of the title, abstract and keywords, the next stage is the extraction of the data relevant to the revision. After reading the 29 selected texts, it was found that 16 articles were not fully compatible with the requirements established in the protocol; 1 article was not available online and; 1 article did not present its complete text in Portuguese, English or Spanish; thus, 11 was the final number of papers relevant to the review.

4. Data Extraction and Results

Before describing the discussions collected through the review, some characteristics of the relevant papers need to be described. The 11 selected papers were written by a total of 39 authors, namely professors and researchers affiliated with universities and members of governmental research bodies, who published in 8 different scientific journals. Notably, among the authors' research areas, physics, mathematics and engineering are the ones with most research studies. Table 1 shows the main characteristics of the papers, authors and journals.

As selected all articles must necessarily meet at least one inclusion criterion, and none of the exclusion criteria, the group of studies shown in Table 1 allows us to identify the degree of empirical importance for this article, so that, the greater the number of inclusion criteria identified in an article, the greater the wealth of information for the analysis proposed in the objectives of this study.

Among these criteria, only (I-1) was present in all the studies of the group of selected texts, that is, articles that did not present at least methods and / or techniques for ECI construction, did not provide the necessary conditions for the development of the goal of this study. The (I-1) criterion allows us, to a certain extent, to understand how literature moves towards the propositions of measuring the degree of sophistication of an economy.

The second most frequent criterion was I-2, found in 8 articles of the review (articles 1, 3, 4, 5, 6, 9, 10 and 11). The focus of this criterion is to highlight whether or not the authors found a relationship between the level of sophistication of the economy and economic growth, which will also be discussed in this paper.

Table 1 - Characteristics of selected papers, in alphabetical order of authors

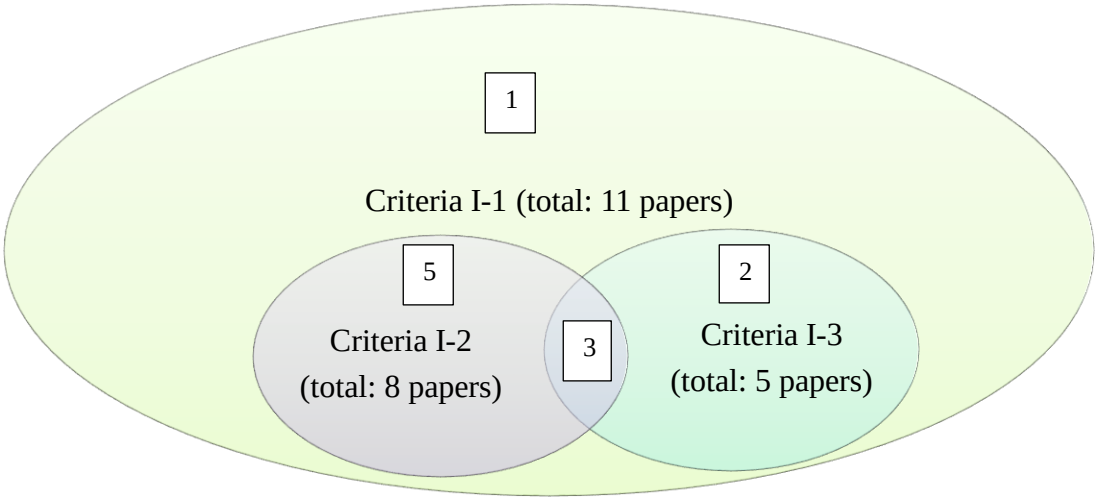
Authors	ID	Institution/Country (as described on paper)	Year of publication	Periodic
Chávez, J. C. & Mosqueda, M. T. & Gómez-Zaldívar	1	Bank of Mexico/Mexico University of Guanajuato/México	2017	The Review of Regional Studies
Gao, J. & Zhou, T.	2	University of Electronic Science and Technology of China/China	2018	Physica A: Statistical Mechanics and its Applications
Hidalgo, C. & Hausmann, R.	3	Center for International Development/USA Harvard University/USA	2009	Proceedings of the National Academy of the Sciences of the United States of America
Krantz, R. & Gemmetto, V. & Garlaschelli, D.	4	Leiden University/Netherlands IMT School for Advanced Studies/Italy	2018	Entropy
Operti, F.G. & Pugliese, E. & Andrade, J.S., Jr.& Pietronero, L.& Gabrielli, A.	5	Federal University of Ceará/Brazil University of Rome/Italy Sapienza University of Rome/Italy World Bank Group/USA	2018	PLoS ONE
Reynolds, C. et al.	6	University of South Australia/Australia University of Sheffield/United Kingdom SA Department for State Development, Adelaide/Australia EconSearch Pty Ltd/Australia University of Adelaide/Australia	2018	Regional Studies
Salles, F.C. & Rocha, E.M.P. & Bessa Porto, I.V. & Vasconcelos, F.L.	7	Federal University of Goiás/Brazil João Pinheiro Foundation/Brazil Minas Gerais Government/Brazil	2018	Brazilian Journal of Innovation
Stojkoski, V. & Utkovski, Z. & Kocarev, L.	8	Macedonian Academy of Sciences and Arts/Macedonia Cyril and Methodius University in Skopje/Macedonia University Goce Delčev in Štip/Macedonia	2016	PLoS ONE
Tacchella, A. & Cristelli, M. & Caldarelli, G. & Gabrielli, A. & Pietronero, L.	9	University of Rome/Italy IMT, Institute for Advanced Studies/Italy London Institute for Mathematical Sciences/United Kingdom	2012	Scientific Reports
Vinci, G. V. & Benzi, R.	10	University of Rome/Italy	2018	Entropy
Zhu, S. & LI, R.	11	Hunan University/China	2017	Applied Economics

Source: self-elaboration.

Finally, the criterion of the study (I-3), ‘obtaining the degree of economic complexity at the regional level’, was the one with the lowest strength, present in only 5 articles (1, 3, 6, 7 and 8).

This criterion is aimed at expanding the geographic scope of the analyses of economic complexity traditionally found in the scientific literature. As mentioned above, the themes of economic complexity arose from the point of view of trade relations among countries. Therefore, finding works that conform to this criterion allows us to corroborate or, at least, to adapt the concepts of complexity under the regional scope. Figure 1 groups the works in order to demonstrate the arrangement obtained after the number of articles was reviewed and their respective inclusion criteria was satisfied.

Figure 1 - Venn diagram of satisfied inclusion criteria



Source: self-elaboration.

As shown in Figure 1 and demonstrated earlier, some papers fit more than one selection criterion. Considering that all the papers adhered to the criterion (I-1), the positive articles for the set (I-1) and (I-2); (I-1) and (I-3); and, (I-1), (I-2) and (I-3) were obtained. Therefore, in the group of 11 selected articles, all of them presented the inclusion criterion 1; 5 articles adhered to inclusion criteria 1 and 2 simultaneously; 2 articles met criteria 1 and 3; and, 3 articles matched all inclusion criteria concurrently. Table 2 shows the papers and their respective inclusion criteria.

Table 2 - Articles and adherence to the inclusion criteria

Paper's ID	Title	Adherence Criteria
1	Economic Complexity and Regional Growth Performance: evidence from the Mexican economy	(I-1), (I-2) e (I-3)
2	Quantifying China's Regional Economic Complexity	(I-1), (I-2) e (I-3)
3	The Building Blocks of Economic Complexity	(I-1) e (I-2)
4	Maximum-Entropy Tools for Economic Fitness and Complexity	(I-1) e (I-2)
5	Dynamics in the Fitness-Income plane: Brazilian States vs World Countries	(I-1), (I-2) e (I-3)
6	A Sub-National Economic Complexity Analysis of Australia's States and Territories	(I-1) e (I-3)
7	The Low Complexity Trap in Minas Gerais: the challenge of economic sophistication in a commodity exporter state	(I-1), (I-2) e (I-3)
8	The Impact of Services on Economic Complexity: service sophistication as route for economic growth	(I-1) e (I-2)
9	A New Metrics for Countries' Fitness and Products' Complexity	(I-1)
10	Economic Complexity: correlations between gross domestic product and fitness	(I-1) e (I-2)
11	Economic Complexity, Human Capital and Economic Growth: empirical research based on cross-country panel data	(I-1) e (I-2)

Source: self-elaboration.

After the identification of the criteria and organization of the papers accepted, we begin the stage of extracting information that is relevant to the review. In view of the limitation of inclusion criteria adhered to by the papers, extraction of data from the articles is related to the needs established in the review protocol. Therefore, information that has no connection with the objectives of this review does not need to be highlighted and discussed.

In order to understand the paths taken by the literature on economic complexity, the importance of pioneering in Hidalgo and Hausmann (2009) and its developments in Tacchella et al. (2012) should first be highlighted. Both papers propose methods, with different mathematical arrangements, which seek to measure the degree of economic sophistication. With the conduction of the systematic review proposed here, we identified that the two papers are responsible for shaping the empirical research on the theme and serve as a basis for nearly all the studies (except for one) included in this review. In addition to the propositions of such authors, Krantz et al. (2018) and Operti et al. (2018) suggest alternative methods, however, at the time of the preparation of this review, we found no empirical applications with those methods because the year of publication (2018) of these two articles was recent.

Although ideas related to the sophistication of the structure of the economy can be related to the classical economists, Hidalgo and Hausmann (2009) are considered to be the pioneers in the structured measurement of the degree of an economy's complexity. The authors have developed a way of understanding economic growth in which complexity has the main role for countries. They made an interpretation from international trade data through a binary network, in which countries are connected to the products they export. This made it possible to quantify the degree of sophistication of the economy by characterizing the structure of this network (Hidalgo & Hausmann, 2009).

To this end, the authors used data from Standard International Trade Classification (STIC), COMTRADE and the North American Industry Classification System (NAICS). They created a binary matrix so that they can relate information about the countries and their respective exported products. Thus, the authors proposed the 'method of reflections' to relate information about different exports in such a way that a country has a comparative advantage over other countries (diversity) when considering the number of countries that export the same product (ubiquity) (Hidalgo & Hausmann, 2009).

The result obtained by the application of the method is what the authors refer to as "direct measurement of a set of capacities", which later in Hausmann et al. (2014) (first edition in 2011) was convened to call the Economic Complexity Index. In addition to the attainment of the degree of capacities of an economy, the article sought to relate this characteristic to the countries' income, and the prediction of future growth.

Through regressions, the authors found a tendency for a positive correlation between income levels and growth rate, and the measured country's complexity. International trade data between 1985 and 2005 were used and divided into two periods of 10 years and four periods of 5 years to construct the variables of economic complexity explaining the growth rate of per capita income of the countries (dependent variable).

On the other hand, Tacchella et al. (2012) also proposed to measure the interaction between economy sophistication and income level but using methods that differ from those of Hidalgo and Hausmann (2009), however. For them, the relationships between product complexity and country capabilities should be treated non-linearly, unlike the proposal of the method of reflections.

When it is found that a product is produced by a developed country, little can be learned about the complexity of this product because this type of country can export numerous types of

products. However, when a country still under development can export a particular type of product, there is a high probability that such a product requires low levels of economic sophistication (Tacchella et al., 2012). This is the great argument that shapes the justifications behind the authors' mathematical model: when it is reasonable to measure the competitiveness of a country by adding the quality and complexity of its products, it is not feasible to adopt the same concept to measure quality and complexity of the products themselves. In general, the complexity of a product cannot be defined as the average capacity of a producing country (Tacchella et al., 2012).

Therefore, the authors argue that, in some way, by adopting a group of countries for the empirical evaluation of the level of sophistication of a product, the countries that produce it must be adjusted in a non-linear way to their competitive structure:

> It appears therefore natural, in the definition of the complexity of the product, to weight the complexity of the productive systems of its exporters in a highly nonlinear way, so that the information that such a product is produced by some scarcely competitive countries is sufficient to conclude that the complexity of the product is low. Consequently, the only possibility for a product to have a high qualitative level (or complexity) is to be produced only by highly competitive countries. In summary our method consists in coupled non-linear maps whose fixed point defines a new metrics for the Fitness of the countries and the Complexity of the products. In this method each iteration adds new information in the system and the distributions of the two metrics become broad Pareto-like. Tacchella et al., 2012, p.1.

In this way, Tacchella et al. (2012) propose to define an interaction process by improving the Reflex Method, and coupled maps of the economic fitness (a measure of economic aptitude for the production of certain products) of the countries and the complexity of the products; thus, one can obtain fixed point values independent of the biases derived from monetary values implicit in costs, price speculations, pricing inefficiencies and others. This means that, for economic fitness, it is natural that it is proportional to the sum of products exported by countries weighted by the complexity of their products. For products, if their complexity is inversely proportional to the number of countries that export it and, in case a country obtains high values of fitness, this should reduce its weight at the limit of product complexity. Therefore, low fitness countries can make a major contribution to the product's complexity values (Tacchella et al., 2012).

Based on this concept, the authors, in order to compare their measure of complexity with that of Hidalgo and Hausmann (2009), consider a simplification of countries in a world composed of four nations. In the first place, the complexity of products is highly dependent on the countries that produce it, especially in the case of countries with low levels of complexity, a fact ignored in the proposal of Hidalgo and Hausmann (2009). This fact implies a more accurate adjustment to the countries' fitness in comparison to ECI (Tacchella et al., 2012); however, when trying to understand the dynamics of regional complexity, it is not always correct to confirm this assertion.

The third proposal of measurement of economic complexity, as suggested by Krantz et al. (2018), shows the importance of improvements in the use of the concept of revealed comparative advantages (RCA), originally introduced by Balassa (1965), and used by Hidalgo and Hausmann (2009) and Tacchella et al. (2012) for the design of their respective indicators. For this purpose, it is necessary, in a preliminary way, to identify the statistical relevance of the country / product information contained in the matrices of comparative advantage (Krantz et al., 2018).

Based on the principle of maximum entropy, the authors proposed a method capable of improving the traditional method of limits on RCA, which, once larger than the unit value, can demonstrate the importance of a given product to a country or represent only the statistical fluctuations of information over the years, something that allows noise in the results obtained on the sophistication of the economy. Therefore, the traditional RCA calculation method, which extends it to the categories of exporters, importers, and commodities, and controls the probabilities of links between products and countries, is replaced with the method which measures the probability distribution in each product / country relationship of the matrix (Krantz et al., 2018).

> The innovation of this paper is that we replace the current method with a null model that extends the RCA to three dimensions (exporter, importer and commodity), mimics the original network in its sparsity by controlling the probability that a link exists, and includes a probability distribution (with the expected weight and variance thereof) for each link weight in order to make statistically justified filtering choices. Krantz et al., 2018, p.4.

To test the new proposal, the authors used the results found by Tacchella et al. (2012) and tested them under the new proposed approach. For the ranking of countries, Krantz et al. (2018) found that there is some stability in the variations of top-tier countries in the application of the new method versus the original method. Regarding fitness and its correlation with the per capita product, the authors see, as a great difference, the lowest standard deviation in comparison to the

Tacchella et al. (2012) method, which means some improvement of the index for the use of prediction economic growth (Krantz et al., 2018).

In order to capture the complexity and identify the differences between the indicators of complexity for the regional reality, Gao and Zhou (2018) proposed the measurement of the degree of sophistication of the economy in the manner of Hidalgo and Hausmann (2009) and Tacchella et al. (2012) and related it to regional economic growth. However, the studies of Gao and Zhou differ from previous research in some respects. The paper seeks to understand the dynamics of the economic complexity of the 31 Chinese regions (also referred to as provinces) and their relationship with economic growth and income disparity from 1990 to 2015.

In order to calculate the different measures of complexity, Gao and Zhou (2018) used non-international trade data, unlike the first studies mentioned here; particularly, data on the quantity of publicly listed companies in the two largest Chinese stock markets. They found 2,690 companies belonging to 70 different sectors of the economy and drew a parallel with the analysis of countries originally proposed by Hidalgo and Hausmann (2009).

Among the results, the authors first seek to understand if, in fact, there is any relationship between development and levels of complexity at the regional level. To this end, they correlate per capita product data with the ECIs they had collected. Using Pearson's correlation coefficient, they found that, for the years 2000 and 2015, on average, provinces with greater complexity had higher rates of development. However, over time, they found that the dynamics of the provinces also depends on another factor:

> To further investigate how economic development depends on the complexity, we move from the static pictures to the dynamics of provinces in the compound ECI-ln(GDPpc) plane from 2000 to 2015. […] the dynamics of the provinces in this plane is, to some extent, heterogeneous but with two emergent trends. On the left and central sides, we observe a laminar regime, where ECI is linearly and positively correlated with ln(GDPpc), supporting that ECI is a driving force of economic growth. Countries locating in this laminar regime enjoy a slow but stable economic development. On the right side, we observe a chaotic regime, where the dynamics of provinces are less predictable due to the larger fluctuations of ECI. However, countries locating in this chaotic regime developed much faster and achieved a higher level of economic development. Gao & Zhou, 2018, pp.1595-1596.

After correlating complexity and level of income, the authors compared the differences between the measures of complexity (ECI vs. fitness measures) and their respective powers of prediction of growth. In order to answer the first point, a ranking of complexity of the two measures was designed. They showed that, among the provinces, the higher and lower sophistication index groups achieved similar patterns in both methods. However, by applying Pearson's correlation coefficient to the ranking indexes, over time, the authors found a positive and significant correlation, which suggests that both methods are somehow consistent and stable at the regional level (Gao & Zhou, 2018),despite inconsistent when compared to rankings in international level.

> […] The result is notable since previous studies based on world trade data found inconsistency of ECI and Fitness methods in ranking countries. Here, our empirical results based on firm data at regional level suggest that the two methods are comparative. Considering that there is no ground truth in rankings in terms of economic complexity and the two methods have distinctive intuitions and formulations, it is hard to identify the best methods in practices, leaving the problem being still complicated. Indeed, the discrepancies of these […] measures of economic diversity urge on the development of new regional economic complexity metrics. Gao & Zhou, 2018, p.1597.

Finally, the study of Gao and Zhou op. cit. sought, through multivariate regressions, to identify if the variations in income levels of the provinces are due to the degree of sophistication of their economies. Thus, using ordinary least squares, models were estimated containing the per capita GDP of the regions as the dependent variable, and independent control variables such as population, level of education, urbanization, innovation and trade. In addition, the sophistication measures adopted were used in separate estimates to capture their respective levels of explanation for income variations.

When comparing both techniques together with other structural variables of an economy, their results showed that although Fitness has a slightly lower explanatory power than ECI, the indicators are comparable and can be considered robust in explaining regional economic development (Gao & Zhou, 2018).

Following the reasoning of the understanding of regional complexity, Chavez et al. (2017) investigated the dynamics of economic sophistication in the Mexican states in order to identify the structure of factors that influence Mexican regional economic growth. To this end, the authors calculated the Economic Complexity Index of the states, using the method of reflections, as

proposed by Hidalgo and Hausmann (2009), and related it to both the growth rates of the Mexican states and the income level of the states, through linear regressions.

For calculating ECI (and in the background, calculating the complexity of activities), the authors used census data, available from the Mexican National Institute of Statistics and Geography every five years, based on the number of people employed by economic activity during the period of 1998 and 2013. It is worth mentioning that the number of economic activities established during the analyzed period has changed; it was 797 in 1998; 866 in 2003; 882 in 2003; and 883 in 2008.

After a primary analysis of the complexity of the Mexican states, the authors found a relative regional pattern in the degree of sophistication of the economy so that the geographic arrangement of the ECI is found in greater absolute numbers in the states of the north region of the country and more leniently in the southern states.

> Furthermore, using the results from 2013, we show that the estimated measure of complexity displays a clear regional pattern. […] states in the northern region are among the most complex economies (five out of the six states in this region are in the group comprising the most complex economies). States in the central regions tend to be located at intermediate levels of complexity. Finally, most of the states that belong to the southern region are classified within the group comprised of the least complex economies in the country (six out of eight states are in the lowest part of the classification). Chavez et al., 2017, p.207.

To respond to the relations between complexity and growth, Chavez et al. (2017) estimated a growth regression whose dependent variable is the annual average growth rate of GDP per capita for the periods 1998-2003, 2003-2008 and 2008-2013. Among the independent variables are the logarithm of GDP per capita of each period, ECI at the state level at the beginning of each period, and finally two dummy variables, one for states considered to be oil producers (states with more than 5% of its product derived from the extraction of the commodity) and another one that captures the temporal effects that affect all the states in the established periods of time.

For the variables obtained, the authors found positive correlations between degree of sophistication of the economy and rate of product growth per person. In addition, states with high levels of dependence on oil exploration had lower growth rates.

Operti et al. (2018) introduced a conceptual adaptation to the method proposed by Tacchella et al. (2012), which they call Exogenous Fitness, to the regional analysis of degree of sophistication

of the economy. For the authors, products have an intrinsic complexity, reflected by trade between countries on a global scale, while when such complexity is brought to the scope of regions of the same country, such complexity may suffer from local bias, hindering the accuracy of results (Operti et al., 2018).

To resolve this problem, the authors sought to understand the regional dynamics of the complexity of the products and fitness of the Brazilian states. First, they obtained the same indicators as Tacchella et al. (2012); after that, they used the values obtained by Fitness for complexity of the products exported by the Brazilian states. They then used the information from the matrix of comparative advantage and from the complexity of the products to calculate the fitness of the Brazilian states (Operti et al., 2018).

In applying the new method and obtaining its variables, the authors organized their results in order to rank the Exogenous Fitness of the states from 2000 to 2014 and found that the states of the center-south of the country have higher levels of sophistication. This result is in accordance with other variables such as HDI and GDP (Operti et al., 2018). In addition to analyzing the scenario of the Brazilian states, the authors proposed and checked a method called Selective Predictability Scheme: the evolution in the real GDP of the states according to their Fitness. They found two groups of states: those with high and those with low predictability of growth. By identifying which states in regions of high predictability coincide with states with higher Exogenous Fitness indexes (and high GDP states are not necessarily in this group), the authors suggest that their indicator seems to be a good predictor of economic growth (Operti et al., 2018).

Reynolds et al. (2018) also seek to understand economic complexity at the regional level, using the method proposed by Hidalgo and Hausmann (2009). The authors used international and interstate trade data dis-aggregated in 9 Australian regions and 506 different activities to calculate and compare the dynamics of the Economic Complexity Index and the Complexity Index of Products in the year 2009.

Although they did not use econometric tools to identify the cause-effect relationships between growth and complexity , the authors were able to identify patterns among regions with higher levels of income and higher levels of sophistication, as well as identify a greater ease of growth in more complex Australian regions in comparison to less complex ones (Reynolds et al., 2018).

Salles et al. (2018) used the tools offered by the Dataviva platform (which provides values for the Economic Complexity Index of Brazilian States and Municipalities) from 2002 to 2014. They analyzed trade data to understand the dynamics of the economic complexity of the Brazilian states within the said period. In an effort to understand the regional supranational movements, the authors decided, at first, to rank the Brazilian states in peak years, according to their respective ECIs, and, secondly, to observe if, in the analyzed period, there was any relation between the level of sophistication of the state economies and their respective levels of per capita income.

In an attempt to identify some relationship between income and sophistication, the authors used regressions with panel data for the set of 27 Brazilian states from 2002 to 2014. In addition to GDP per capita, as a dependent variable, they also focused on ECI, by measuring degree of complexity of the state, share of exports in GDP, share of commodity exports in GDP and population size. The regressions were estimated in two stages: in the first stage, the level of the sophistication variable was not considered. The results showed that the Economic Complexity Index of the states presented positive coefficient statistical significance to explain the different income levels of the Brazilian states (Salles et al., 2018).

To provide an alternative to traditional measures of complexity measurement, Stojkoski et al. (2016) added the role of services in achieving the level of sophistication of the economy and its relation to economic growth. It is evidenced that service complexity indices are generally higher than those obtained with product data; this is a reflection of a general trend among service-intensive countries of having better positions in development ranks than goods-intensive countries (Stojkoski et al., 2016).

Using the methods of Hidalgo and Hausmann (2009) and Tacchella et al. (2012), the authors designed the two indicators using data on services and goods, thus allowing for comparison and possible disparities. Data on international trade in services were collected from the World Bank database, broken down into 12 segments. The rationale behind the application of this data for design of the index follows the same design logic for indexes that use international information on trade of goods, as seen previously. Data on international trade in goods were collected from the COMTRADE database.

Stojkoski et al. (2016) tested two econometric models for two different periods (1988-1998 and 1998-2008). The first one relates economic growth rates to the measures of complexity derived from the linear method, and the second one captures such a relation using nonlinear measures. In

general, there is a correspondence between the predictive power of growth with both methods tested; however, by changing the level of aggregation, different results are obtained (Stojkoski et al., 2016).

Vinci and Benzi (2018) sought to identify if it is possible, in any way, to correlate the degree of sophistication of the economy with its level of output. To do so, using the tools offered by Takens' Theorem, we tested the correlation between the complexity measure of Tacchella et al. (2012), Fitness, and the per capita gross domestic product of a group of countries. In their results, the authors found high correlations between the study variables; however, this behavior occurred only in groups of relatively rich countries. This fact testifies to the robustness of Fitness as a measure of competitiveness between countries (Vinci & Benzi, 2018).

Using international trade data in a group of 210 countries from 1995 to 2010, Zhu and Li (2017) investigated the impact of economic complexity and human capital on economic growth. To this end, the ECI is calculated according to Hidalgo and Hausmann (2009) and, through regressions, the authors sought to show how these variables influence growth rates in the short and long term. In addition, the authors identified the sensitivity of the values established in the comparative advantage matrix and how such advantage is related to the regressions tested. The findings indicate that economies with higher levels of income have higher rates of economic complexity and human capital. In addition, these variables have a strong influence on growth rates in the short and long term (Zhu & Li, 2017).

In view of these considerations, Table 3 summarizes the information extracted from the review according to the needs established in the protocol:

Table 3 - Summary of data extraction

Paper's ID	Complexity Measure	Data Format	Relation Between Complexity and Growth	Analysis' Geographic Level
1	ECI	Employment	+	Regional
2	ECI and Fitness	Number of Companies	+	Regional
3	ECI	International Trade	+	International
4	Fitness (adapted)	International Trade	+	International
5	Fitness (adapted)	International Trade	+	Regional
6	ECI	International Trade	Does not apply	Regional
7	ECI	International Trade	+	Regional
8	ECI and Fitness	International Trade	+	International
9	Fitness	International Trade	Does not apply	International
10	Fitness	International Trade	+/-	International
11	ECI	International Trade	+	International

Source: self-elaboration

5. Final Remarks

Given the increasing academic relevance of the themes of economic complexity, the present systematic review sought to select papers with empirical applications and to understand the steps of the present and the projections for the future of the field. The evaluation of the studies indicated scientific articles that could somehow answer questions about the methodological models applied in current scientific reality, and it was responsible for shaping the methods and techniques applied in this review. The initial selection of the studies found 29 articles in a universe of 472. After these texts were read in full, data were extracted from a group of only 11 articles, which were strictly aligned with the objectives of this review. What can be observed is a nascent literature, but with a rapid growth of academic importance because of the exhaustion of the traditional proposals for understanding the directions of economic growth as well as the need for alternatives that introduce non-monetary aspects to economic understanding.

An important fact found in the review is that, since the more traditional empirical literature on the subject is still nascent, its application to regional realities is still nascent. This can be identified by the fact that in a significant universe of studies, only 5 presented proposals for methodological adaptation to the regional scope. Thus, while the small number of proposals

impoverishes the basis for formulating new ideas, this fact increases the relevance of an additional contribution to the literature in the field, something that the present work seeks to propose.

With regard to the panorama found by the review, there is a greater application of the methods that seek to identify the level of economic sophistication in the international scope and there is a debate, although not in all the texts, on the degree of quality and correct applications of the proposals by Hidalgo and Hausmann (2009) and Tacchella et al. (2012). This indicates that it is the current background of the empirical discussion of the theme. Therefore, not only because the pioneering works on the subject are dated from recent times, but also because of the merit of the issues discussed academically, there are indications that there is still am ongoing process of consolidation of what is relevant or not for the literature.

In spite of methodological differences in obtaining the degree of sophistication of the economy, the literature generally seems to move towards the realization that the productive structure of a country or region directly influences the level of growth, and that high income is related to high economic complexity. Thus, other directions for understanding the causes of diffuse economies in the world, or even in the same region, other than the traditional ones already depleted, provide ways to broaden the understanding of problems and expand the choice of possible solutions.

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