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Using Indicators of Entrepreneurial Ecosystem Quality for Segmenting Countries: A Biclustering Approach

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Abstract – The term entrepreneurial ecosystem emerged in the 1980s and 1990s and stands on the premise that entrepreneurship should be observed and studied through the perspective that incorporates the role of social, cultural and economic forces. A rich entrepreneurial ecosystem has been described as one with a strong entrepreneurial culture and supportive public policies, which leads to the creation of a socio-economic system that supports the creation and growth of new ventures. Policymakers and decision-makers were in need of quantifying the quality of the entrepreneurial ecosystem. Their need led to the development of different metrics and approaches. The first direction proposes using individual indicators. However, contemporary literature suggests that individual indicators cannot measure the complexity of the entrepreneurial ecosystem. As a remedy, multidimensional approaches, such as composite indicators, were proposed. So far, several composite indexes related to entrepreneurship have been proposed, whereas the Global Entrepreneurship Index (GEI) stands out for its methodology and continued publication. The research question of this study is how countries can be segmented based on the quality of the entrepreneurial ecosystem measured by the GEI. The statistical analysis used to answer the research question is biclustering, while the specific algorithm is a variant of the Xmotif biclustering. The data on which the analysis was conducted was for the year 2018. It is believed that the obtained results could shed light on two aspects. First, the results could show whether there is a need to collect data for 14 pillars or whether the structure of the GEI can be simplified. Second, the results could yield information on how the observed 137 countries can be grouped. The presented research could act as a driver of further research on composite metrics in the field of entrepreneurship, on the GEI, as well as the application of advanced statistical methods for segmentation analysis.

***Keywords*:** Global Entrepreneurship Index, Entrepreneurial success, Segmentation analysis, Biclustering

1. Introduction

Entrepreneurs differentiate due to their ability to tolerate risk and ambiguity, promote creativity, be courageous, and make unconventional decisions [1]. Teixeira et al. [2] explain entrepreneurship as the creation and fulfilment of plans and their establishment with developed business abilities to gain finance and deal with risk and business management, with the ability to always be updated with financial reserves. To be successful, entrepreneurs need an environment that enables and supports innovative economic activity. This environment, in a form of an entrepreneurial ecosystem, is the subject of many papers in recent years [3]. Entrepreneurial ecosystems continually arise through micro, meso and macro level processes, but a universally accepted definition of an entrepreneurial ecosystem is yet to emerge, although there are many instances where researchers identified its domains, components and general nature [4], [5]. In their work, Acs et al. [6] describe an entrepreneurial ecosystem as resources and factors needed for the creation of economic knowledge through the engagement of entrepreneurs. Isenberg [7] proposes six dimensions of an entrepreneurial ecosystem, giving insight into different factors that can influence it: policy, availability of human capital, financial capital and funding, market, culture and support from non-government institutions. Stam & Van de Ven [8] state that the entrepreneurial ecosystem comprises independent actors and factors that support, and in some ways constrain entrepreneurial activity within a geographical territory, also stating that there is a strong correlation between the number of high-growth firms and the quality of the entrepreneurial ecosystem. It shows that most explanations of an entrepreneurial ecosystem revolve around a combination of different factors and elements that create a culture of entrepreneurial activity support [9]. A good entrepreneurial ecosystem enables entrepreneurs to achieve greater economic output regardless of their quality, pointing to the importance and relevance of the subject [10].

Entrepreneurial ecosystems are used to explain regional and entrepreneurial activity within certain industrial sectors. The use of the word ecosystem signals the interconnectedness of all the agents within it that cannot exist without each other. This interconnectedness generates economic outputs for all involved, enabling growth. The role of an entrepreneurial ecosystem is to enable the exchange of knowledge between its participants, creating added value, both economic and other, thus increasing the productivity of entrepreneurship [11]. An entrepreneurial ecosystem is particularly important and should be of interest when many innovative ideas are generated outside of big, industry-leading firms since, in this instance, entrepreneurship and entrepreneurs are the main driving force of the whole regional ecosystem [12]. In their paper, Cantner et al. [12] present an entrepreneurial ecosystem lifecycle model consisting of five phases: birth, growth, maturity, decline and re-emergence. This suggests that there is a never-ending cycle and need for a high-quality entrepreneurial ecosystem that drives economic growth and prosperity.

One of the important factors of entrepreneurial ecosystems are universities because they often generate new knowledge necessary for innovative business ventures. This is supported by Theodaraki et al. [13] who state that incubators are primarily sponsored by academic institutions. However, universities and industry come to a clash when it comes to the distribution of generated knowledge, since universities want to share their findings through publications, while the industry might want to protect their findings as intellectual property. Segmentation analysis has been previously performed on entrepreneurship-related data. For example, Cardon et al. [14] segmented entrepreneurs from the US into five clusters named: Ambitious, Accomplished, Lifestyle, High rollers, and Striving. In a more recent study, Ionescu et al. [15] clustered countries based on the results of several composite indicators of entrepreneurial activity. They segmented European countries into four clusters. Costa e Silva et al. [16] conducted a time-series clustering analysis for 20 years using different clustering algorithms. It is clear that there is a need among stakeholders for such analysis and information. Policymakers and decision-makers were in need of quantifying the quality of the entrepreneurial ecosystem. Their need led to the development of different metrics and approaches. The first direction proposes using individual indicators. This, at a glance, the straightforward approach can be useful; however, contemporary literature suggests that individual indicators cannot measure the complexity of the entrepreneurial ecosystem. As a remedy, multidimensional approaches have been proposed. When it comes to multidimensional metrics, the most common ones are composite indicators – single-number metrics created as a combination of values of multiple indicators. So far, several composite indexes related to entrepreneurship have been proposed, whereas the Global Entrepreneurship Index (GEI) stands out for its methodology and continued publication [17]. Since the entrepreneurial ecosystem consists of different elements and outcomes, the GEI is considered an important metric measuring all the interactions, abilities and attitudes at a country level [6].

The research question of this study is how countries can be segmented based on the quality of the entrepreneurial ecosystem measured by the GEI. The statistical analysis used to answer the defined research question is biclustering, while the specific algorithm is a variant of the Xmotif biclustering. The data on which the analysis was conducted was for the year 2018. It is believed that the obtained results could shed light on two aspects. First, the results could show whether there is a need to collect data for 14 pillars or whether the structure of the GEI can be simplified. Second, the results could indicate how the observed 137 countries can be grouped.

The paper is segmented as follows. The second section of the paper is related to the literature review on indicators of entrepreneurial activities and the Global Entrepreneurship Index (GEI) and its pillars. In the next section, we briefly outline the theoretical aspects of the biclustering approach. In section four, we present the segmentation analysis results. The last two sections of the paper are related to the discussion and concluding remarks.

2. Literature review

Constant changes and competitive markets today affect companies to measure their business results and monitor their values, which can be done with the application of performance management. The performance management system presents the process(es) of estimating the differences between desired and actual outcomes, identifying critical differences and proposing and monitoring the realisation of corrective actions to close all performance gaps [18]. Performance measures transmit to the employees and management what needs to be done and help them to understand what is required to be done [19]. Identification of performances encompasses the identification of performance indicators. These indicators should provide *control* (for managers and employees to evaluate and control performances of the allocated resources), *communication* (between internal employees and external stakeholders) and *improvement* (to identify gaps and be used for the adjustment or planning of corrective measures) [20].

Szerb et al. [10] consider that the relationship between various performance metrics and entrepreneurship has an impact on economic outcomes, such as: the selection of the performance measurement, type of geographical unit, entrepreneurship definitions and measurements, and modelling strategy. The entrepreneurial activity presents the level of participation of the population in the creation and management of companies and can be observed as the main indicator of the development of entrepreneurial companies at the regional level [21].

Many authors have dealt with the topic of the application of performance indicators in the field of entrepreneurship and entrepreneurial activities. These examples are presented in the following subsection.

2.1. Indicators of entrepreneurial activities

Doran, McCarthy and O'Connor [22] have applied 14 different entrepreneurial indicators to analyze the contribution of entrepreneurial aspirations, activity, and attitudes to gross domestic product per capita. Caliendo, Goethner and Weißenberger [23] have measured entrepreneurial persistence with two indicators of survival and hybrid persistence. Stam [24] has used indicators of high-growth firms to measure the output of entrepreneurial ecosystems. Prayetno and Ali [25] consider that entrepreneurship indicators are the added value in the aspects of knowledge. Stuetzer et al. [26] state that an entrepreneurship culture has an impact on entrepreneurship indicators related to the performance and behavioural view affecting economic growth. Nicotra et al. [27] have presented eco-output measurements by classification into three categories of indicators: gross entrepreneurship activity indicators, performance-based productive entrepreneurship indicators, and assumption-based productive entrepreneurship indicators. Alam, Kousar and Rehman [28] have defined six performances with a variable number of indicators to measure entrepreneurial motivation and entrepreneurial behaviour. Stam and Van de Ven [8] proposed a framework for studying entrepreneurial ecosystems and developed a measurement instrument of its elements to define an Entrepreneurial Ecosystem Index (EEINDEX) to examine the entrepreneurial ecosystem's quality. Dilli, Elert and Herrmann [29] defined a set of indicators to explain differences in types of entrepreneurship between countries.

The problem with entrepreneurship measurement is that it is not a homogenous unit [30]. One of the methods to measure entrepreneurial activity is the Global Entrepreneurship Index (GEI). GEI combines indicators of entrepreneurial activity and institutional variables with an algorithm that creates the link between entrepreneurship and institutions [31].

2.2. Global Entrepreneurship Index (GEI)

The Global Entrepreneurship and Development Institute (GEDI) acknowledged the need of various stakeholders for a composite metric and ranking of countries based on the achieved level of entrepreneurial ecosystem quality. Therefore, they proposed and published the GEI in 2008 [32]. The index had to answer two main questions: why an individual chooses to become an entrepreneur while others do not and why entrepreneurial activities differ across countries. Since its launch, the index has attracted the attention of not only academics [33], [34] but of governments [35] and newspapers [36].

The index, in the edition 2018, consists of 14 pillars: Opportunity Perception (OP), Startup Skills (SS), Risk Acceptance (RA), Networking (NW), Cultural Support (CS), Opportunity Perception (OP), Technology Absorption (TA), Human Capital (HC), Competition (CP), Product Innovation (PdI), Process Innovation (PcI), High Growth (HG), Internationalisation (Int), and Risk Capital (RC). Pillars are formed using two or three indicators, depending on the pillar; in total, there are 14 pillars, 28 variables and 49 indicators. Our analysis focused on pillar values, as they were publicly available on the GEDI website. Also, we focus on the data for 2018, as the technical report and the data were freely available on the GEDI repository [17].

It can be concluded that the GEI is a composite indicator with a complex structure aiming at quantifying the complex issue of entrepreneurial ecosystem quality. According to its creators, Acs and Szerb [37], their approach to entrepreneurship is specific for several reasons. First, they observe entrepreneurship as a concept of quality. Second, they believe that both institutional and individual factors should be taken into account. Third, measuring the pillars of entrepreneurship is based on a benchmark of the best five percent existing achievements for each particular pillar. Fourth, the average of 14 pillar values was equalised to provide the same marginal effect. And final, the pillars are observed as the building blocks of entrepreneurship, not as independent elements of a system. Taking all this into account, it can be said that the GEDI is a comprehensive, acknowledged composite indicator in assessing countries' entrepreneurial activities.

3. Applied statistical analysis – Biclustering

The main research question of this study is to group countries based on the achieved level of entrepreneurial ecosystem quality. This research question, therefore, strives to segment countries. Segmentation of entities can be done using clustering

and biclustering analysis. Clustering aims at grouping entities which behave in the same way considering all indicators, while biclustering aims at grouping simultaneously entities and indicators of behaviour [38]. Although the algorithms of biclustering are more complex and difficult to comprehend, they are being used for segmentation purposes not only in the field of gene expression but whereas in contemporary business and market segmentation [39]. Biclustering algorithms first emerged with the study of J.A. Hartigan, a professor of statistics at Yale University, in 1972 [40]. Having in mind that conducting biclustering requires computation power, in the next decades' biclustering did not attract that much attention from academics and practitioners. Biclustering's popularity spiked after 2000 when Cheng and Church [41] introduced a biclustering algorithm known as δ-biclustering. After that, the interest in biclustering started to grow and the number of methods increased continuously. Biclustering is now used in marketing [42], quality management [43] and others. In biclustering, the focus is on detecting local patterns in the data matrix. The goal of the method itself is to identify a group of features that are specific only for a certain subset of entities and form a submatrix of the entire data matrix. A bicluster is a submatrix of matrix A, with not necessarily adjacent rows and columns, which satisfies certain conditions of homogeneity. The total number of biclusters retained and detected depends on the features of the biclustering algorithm that is used, then on the restrictions that are applied, the defined parameters of the algorithm, as well as on the structure of the data set on which the analyses are performed [44]. Based on the type of data used, different algorithms of biclustering are applied. If the observed data is scaled, usually delta biclustering is used [41], while when the data is ordinal, Xmotif algorithm is recommended [45].

4. Results

The initial algorithm applied to the collected data was the algorithm of Cheng and Church [41], known as delta biclustering (BCCC). However, applying the BCCC algorithm did not yield satisfactory results, as the algorithm found only one bicluster, which was the initial matrix. Parameter changes led to the same result. Therefore, another biclustering approach had to be applied. As the initially collected data was firstly ordinal, before being transformed to scale, we believed that an algorithm for ordinal data would be a good solution to the issue faced. The algorithm we decided to apply was the ordinal variant of the Xmotif algorithm proposed by Murali and Kasif [45]. We applied the BCQuestord algorithm, which operates on the principles of the Xmotif algorithm and is specialised for ordinal data [46]. The analysis was done in R programming language, using the RStudio gui, and the package "biclust" [47]. The BCQuestord algorithm has five parameters that have to be determined. As there are no guidelines regarding the values of these parameters, the authors tried several combinations and chose the best combination that led to the best segmentation. Such an approach has been taken in the biclustering literature before [48]. To assess the biclustering structure, we used two metrics: the segment size and the per cent of the sample which was not biclustered [49]. The results indicate that two segments can be made. First, comprising 89 countries and 12 pillars, and the second, comprising 36 countries and 9 pillars. Both segments encompass more than 5% of the sample; they are larger than 7 ($137*0.05\approx7$). At the same time, a small percentage of the sample was not segmented; only 12 countries, which is 8.7% of the overall sample. Descriptive statistics of the two segments are provided in Table 1. The first segment was called the developing segment, as it mostly encompasses the countries which are developing economies in which it was expected to have a developing climate of the entrepreneurial ecosystem. The second segment, visibly smaller in size, is the segment which was named the developed segment. The countries in this segment are already seen as the leaders and drivers of entrepreneurial activity on the global level. It is also valuable to inspect the countries which were not segmented. These countries are mostly middle eastern countries, as well as some economies of the western Balkans. Although these countries have not been segmented together, they can be named transitioning countries.

Table 1: Descriptive statistics of the two retained segments alongside the information on the non-segmented countries.

Segment	Segment name	Segment size	Segment dimensions	Representative countries
1	Developing	89	12	Taiwan, Poland, Cyprus, Turkey, Tunisia, Italy, China, Latvia, Serbia, South Africa, and others
2	Developed	36	9	USA, Switzerland, Canada, UK, Australia, Denmark, Finland, Slovenia, and others
3	Unsegmented	12	/	UAE, Bahrain, Saudi Arabia, Botswana, Croatia, Brunei, Montenegro, Iran, and others

Besides providing the descriptive statistics of the segments, it is valuable to present the bicluster bar chart. The bicluster bar chart is a valuable chart which provides several information. First, it can indicate which pillars are used to form the segments and which are not. This feature can be helpful as it can point out pillars that are not needed to create segments. Reducing the number of indicators, variables and pillars collected can speed up the GEI publication process as well as decrease the costs of data collection and preparation. Second, it provides information on the measured mean values per segment and comparison to the overall sample mean. Comparison to the overall sample mean can be very useful and helpful in describing and a better understanding of the retained segments. The bicluster bar chart is given in Figure 1.

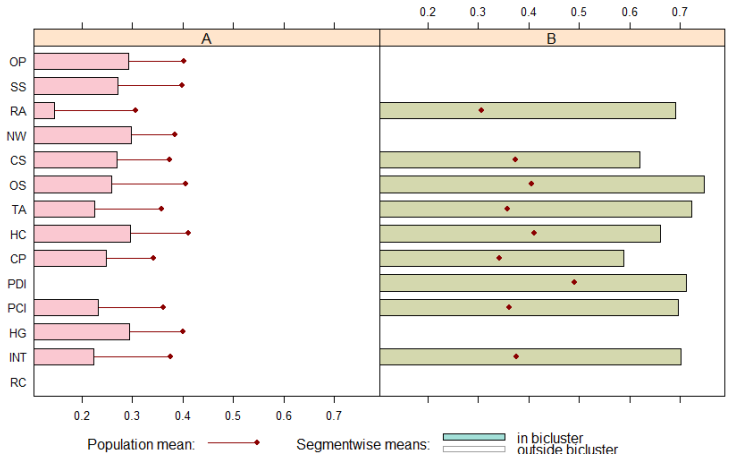

Fig. 1: Bicluster bar chart.

The bar chart indicates that one pillar was not used to form the segments, pillar RC – Risk capital. All other pillars were used. Regarding the comparison to the sample means, it is visible that the countries in the first segment have lower values. The mean values within the segment Developing are marked in red and are on the left side of the population mean, marked with a red square. On the other hand, the countries in the Developed segment have higher values marked in green which are on the right side of the population mean.

5. Discussion

The results of the conducted study clearly showed that countries could be grouped based on the achieved level of entrepreneurial ecosystem quality. If the GEI data is used for segmentation, two segments are distinguished alongside several countries which could not be segmented. For a better visualisation of the results, a world map has been coloured based on the segment to which the country belongs (Figure 2). Countries marked as NA are the countries for which the GEI is not calculated or the R package used does not support it.

The coloured map indicates that countries in North America, West Europe and Australia are leading when it comes to the entrepreneurial ecosystem quality. In these countries, entrepreneurship is supported by the government, and the individuals are motivated to be creative, take risks and become entrepreneurs [50]. Other countries covered by the GEI should be aware that there is a place for further improvement in the entrepreneurial ecosystem, that policies should be changed accordingly, that more support should be provided to the youth and entrepreneurs, internationalisation, and that education on entrepreneurship should be included in high school and university education [51].

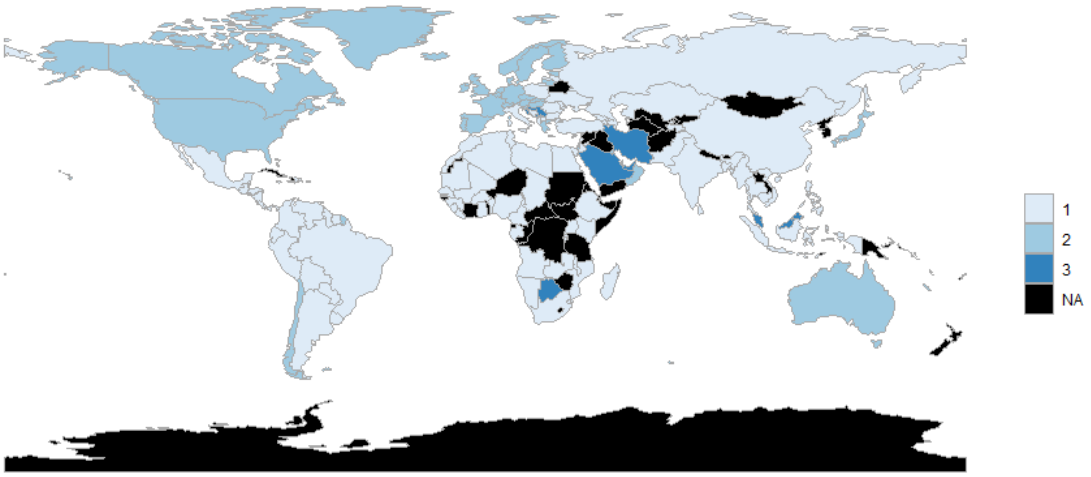

Fig. 2: Segmented world map.

6. Conclusion

The development of an entrepreneurial ecosystem, "an effective environment that will promote entrepreneurial behaviour and provide knowledge and technology transfer on the market" is of utter importance to all stakeholders – from entrepreneurs to universities, the general public, policymakers, to government [52]. Entrepreneurship is considered to be a key factor when it comes to economic growth and recovery, being relied upon to create new growth in developed and to kickstart growth in less developed countries and economies [53]. Because of this, an emphasis is put on the environment in which this entrepreneurial process is taking place, namely the resources and outcomes needed for fruitful entrepreneurship activity [54]. It is because of this that research pertaining to the entrepreneurial ecosystem is of such importance and relevance in recent years.

The results of the study should be interpreted keeping in mind its limitations. The first limitation is that the analysis was conducted on pillar data. Observing the indicator and variable data and conducting the biclustering on more precisely measured data would be interesting. Pillar data represents the aggregated data and, therefore, can mask a certain amount of information and insights. Also, a two-fold segmentation analysis could be performed: in the first step, the exploratory factor analysis could be performed to group the pillar, indicator or variable data, while in the next step, on the newly formed latent variables, a clustering approach could be applied [55].

The presented study can be valuable as it shows how countries can be grouped based on entrepreneurial ecosystem quality. The authors believe that this study could assist decision-makers and policymakers on one side, as well as CEO managers in better understanding the ecosystem they are operating or plan on operating. The application of segmentation analysis in entrepreneurship could help better understand the mechanisms that drive or oppress entrepreneurship and initiate further research on the topic.

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