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# Modeling the Influence of Startup Ecosystem Components: Entrepreneurial Aspect

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**Abstract**. Defining the basis for the development of a country's start-up ecosystems as the basis for activating entrepreneurship is an urgent task of restoring the country's economy. The purpose of this study is to identify ways to improve the country's start-up ecosystem based on the construction of economic and mathematical models for activating business activities. The research methodology is based on statistical research methods, namely dynamics analysis; to assess the strength of the influence of each component of the start-up ecosystem on the change in position in the rating, regression correlation analysis was chosen, which allows identifying the strength of the influence of factors on the final indicator. The components of the start-up ecosystem were investigated, which means an interactive and interdependent set of institutions whose activities create an environment for the qualitative and quantitative growth of start-ups as subjects of innovative entrepreneurship development. The use of statistical analysis methods for the data of the countries, which were grouped into 5 clusters, allowed determining the absolute changes in the values of the Global Start-up Ecosystem Index rating indicators from Start-up Blink: rating change, quantitative component, qualitative component, business environment, general summary. Based on regression-correlation analysis, economic-mathematical models were built, which describe the influence of the components of the country's ecosystem on the change in the rating positions in the section of four clusters, demonstrating: a strong connection between the factors and the result (Clusters 2, 4). Weak connection for the countries of Clusters 3, 5, which indicates the dependence of the development of start-up ecosystems on other factors that are not considered in their description and which affect the development of start-ups and entrepreneurship in the countries of Clusters 3, 5. The practical value of this paper is that the results of the study can serve as the basis for the local and state authorities to form strategies to develop start-up ecosystems at the national and regional level

**Keywords**: start-up, country ecosystem, economic and mathematical model, entrepreneurship, rating



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## INTRODUCTION

The development of entrepreneurship is the key to the economic growth of a country with a market economy, which determines the relevance and necessity of the formation of a comprehensive ecosystem of entrepreneurship development. Its important condition is the creation of not just new firms and start-ups, but rather high-growth firms (HGFs), which cannot be ensured without using an ecosystem approach to entrepreneurship.

Turning to the sources of the mentioned approach, the very term "ecosystem" came into economic circulation from biology. It was first mentioned in the economic context in the work of James Moore (1993), who coined the term "entrepreneurial ecosystem" and believed that the ecosystem includes both the internal and external environment. Thus, apart from owners and employees, adding government agencies, competitors, suppliers, etc. In their study, E. Stam and B. Spiegel (2016) consider the entrepreneurial ecosystem as "a set of interdependent actors and factors that are coordinated in such a way as to ensure productive entrepreneurship in a certain territory", while not identifying with them clusters and innovative systems. What is important is the emphasis that these scientists put – the spread to a certain territory and the shift of attention to entrepreneurship as a whole, rather than the concentration on an individual subject.

The entrepreneurship ecosystem includes such "elements as individuals, organizations, and institutions outside of entrepreneurship that encourage or hinder a person's decision to be an entrepreneur or influence their success in starting an entrepreneurial activity" (Aliabadi *et al*., 2022). This definition focuses on certain components of the ecosystem that should interact with each other. Therewith, the emphasis is on starting one's own business, and not on its growth in the form of the existence of fast-growing companies that cause development.

An interesting idea (Porev, 2018) is that the presence of entrepreneurial structures in the economic system ensures the presence of entrepreneurial ecosystems as an environment for the growth of firms. R. Brown and K. Mason (2017) do not limit the role of entrepreneurial ecosystems to the development of start-ups and believe that the role of large firms is to attract skilled labour, build human potential capable of start-up activities.

In addition, the development of entrepreneurial ecosystems was considered in the studies of O'Connor *et al*. (2018), as well as Haustov *et al*. (2022). Thus, an entrepreneurial ecosystem can be considered as a certain interacting set of institutions and organizations that enter into an interdependent relationship, creating an environment for the successful start, operation, and rapid growth of enterprises.

Further research of the scientific heritage indicates the relevance of investigating start-up ecosystems and their development vectors. Thus, according to Creating a Future-Ready Start-up Ecosystem (2022), the authors identified the obstacles that prevent the start-up ecosystem from reaching its full potential, identified new opportunities, and developed actionable strategies that can help the ecosystem reach new heights. (Agnihotri, 2018) described the modern start-up ecosystem and proved that start-up creation makes "business" a career worthy of attention outside the conventional trade community, a political path for start-up creation and success in scale improvement, combining simplicity and efficient execution with results based on continuous improvement. The authors (Cukier & Kon, 2018) proposed a maturity model for start-up ecosystems that helps understand their evolution and dynamics. Moreover, such a system can serve as a basis for stakeholders in less mature ecosystems to analyse their environment, identify weaknesses, and suggest policies and practical actions to improve their ecosystems after some time.

According to (Segers, 2019), the entrepreneurial start-up ecosystem as a concept appeared quite recently and serves as a framework that allows understanding the environment and its favourable characteristics for entrepreneurial prosperity. An essential element of the new regional entrepreneurship ecosystem is Student Start UP, a joint venture between the University of Applied Sciences and Hasselt University that focuses on student entrepreneurship. Authors such as (Jacobides *et al*., 2018) note two approaches to understanding the start-up ecosystem. In the first approach, the ecosystem is perceived as a group of organizations that are largely interdependent in relation to factors of production and output; in the second – as a system of interdependent technologies. These approaches define two areas of research related to ecosystem analysis: 1) in the field of strategic management; 2) in the field of technology management.

*The purpose of this study:* to establish the vectors of development of the modern start-up ecosystem of countries based on economic and mathematical modelling to ensure the development of entrepreneurship. The task of the research: to cover the essence and components of the start-up ecosystem; to determine dynamic changes in the ranking of countries in terms of the components of the Global Start-up Ecosystem Index from Start-up Blink, which reflects the country's start-up ecosystem (quantitative component, qualitative component, business environment); to build mathematical models that describe the influence of each component of the start-up ecosystem on the change in the ranking position.

## MATERIALS AND METHODS

The data of the Global Start-up Ecosystem Index 2021 according to Start-up Blink (2021), which is the largest comprehensive rating of start-up ecosystems of 100 countries and 1,000 cities of the world since 2013, formed the information base of this study. It presents the ranking of countries, where the Total Score (corresponds

to the position in the ranking) and Rank Change (shows the change in the ranking in 2021 relative to 2020) are noted. The choice of this particular rating is conditioned upon the presence of a structured start-up ecosystem, which is described by components containing appropriate indicators and descriptions. The methodology for calculating the start-up ecosystem index Start-up Blink contains 3 components: quantitative, qualitative indicators, and assessment of the business environment.

The quantitative component shows the level of activity of the ecosystem through its stakeholders and other indicators, such as the number of start-ups, the number of coworking spaces, the number of accelerators, the number of meetings related to start-ups, which allows establishing the level of activity of the start-up ecosystem. The qualitative component of the rating examines the parameters that indicate the qualitative results achieved by the ecosystem. These parameters include an analysis of the popularity of the best start-ups in the ecosystem: traffic, domain rating, customer base; availability of branches and research centres; international technology corporations; branches of multinational companies; investment volume; number of start-up employees; availability of unicorn companies, exit companies, and pantheons. The business environment assessment component combines business and economic indicators at the national level, which focus on overall indicators related to infrastructure, the business environment, and the ability of start-up founders to work freely in each country. The main components of the business environment component are: ease of doing business and registering companies; availability of the internet and its speed; investment in R&D; availability of various technological services (payment portals, travel exchange programs, cryptocurrencies); number of patents per capita; level of English language proficiency, etc.

The methodology of this study is based on statistical methods, namely dynamic analysis, which is used to investigate the absolute change in the ranks of countries in the Global Start-up Ecosystem Index ranking from Start-up Blink, which allows determining dynamic changes by year (2021 to 2020), as well as structural shifts that led to such changes, in terms of components of the index (quantitative component, qualitative component, and business environment).

The dynamics were investigated in terms of groups of countries, which were unified using cluster analysis, which allowed forming 5 clusters, presented in detail in the studies (Dymchenko *et al.*, 2022; Kyzym *et al.*, 2022). To assess the impact of changes in each component of the start-up ecosystem, a regression-correlation analysis was chosen, which allows finding the impact of factors on the final indicator. For the best understanding of how the selected indicators affect the resulting indicator ($y$), a single multivariate regression equation is constructed, which has the following form (1):

$$y=f(\beta, x)+\varepsilon \quad (1)$$

where $x=x(x_1,x_2,...x_i)$ is the vector of independent (explanatory) variables; $\beta$ is the vector of parameters that fall under the definition; $\varepsilon$ is the random error (deviation); $y$ is the dependent variable (the one that is explained).

The calculated coefficients $\beta$ near the arguments show that when the variable $x$ increases by one, the average value of $y$ will increase by the corresponding value of the coefficient $\beta$. The "+" sign next to $\beta$ shows a direct relationship between the corresponding arguments and the occupied value, the "-" sign is the opposite.

The constructed model is verified for authenticity. The most general assessment in this case was provided by correlation and determination coefficients. The relationship between the factors ($x_i$) and the result ($y$) is evaluated using the multiple correlation coefficient ($R$) and the coefficient of determination ($R^2$) according to the Chaddock scale (Table 1).

***Table 1***. *Chaddock scale*

| The magnitude of the absolute value of the correlation coefficient | Characteristics of the linear relationship between random variables |
|---|---|
| up to 0.3 | Almost absent |
| 0.31-0.5 | Weak |
| 0.51-0.7 | Noticeable |
| 0.71-0.9 | Strong |
| 0.91-0.99 | Very strong |

***Source:*** *(Kushnir & Zavalniuk, 2018)*

Within the framework of this study, the influencing factors are as follows: quantitative component ($x_1$), qualitative component ($x_2$); business environment ($x_3$), and the resulting indicator ($y$) is Change ranking. According to the given methodology, a regression-correlation analysis is performed for each cluster, which allows determining

the influence of factors for different types of start-up ecosystems. In addition, within each cluster of start-up ecosystems of the countries included in the rating, a model is built, and its reliability is verified. To generalize the results, a tabular method is also used, which allows visually presenting the changes in the constituent factors and the performance indicator; generalize the model and indicators of its significance and reliability.

## RESULTS AND DISCUSSION

To find the influence of each component (quantitative, qualitative, and business environment) on the overall result and the rating and in the cluster, the dynamics of their change were analysed. The results for clusters are presented in Tables 2-6. Thus, Cluster 1 will be analysed in more detail, which includes only one country that is the absolute rating leader – the USA (Table 2).

***Table 2**. Dynamics of changes in start-up ecosystems in Cluster 1 countries*

| Country | Rating change | Quantitative component | Qualitative component | Business environment | Overall summary |
|---|---|---|---|---|---|
| United States | 0 | -0.33 | 1.29 | 0.3 | 1,253 |

***Source:** compiled by the authors*

Analysis of Cluster 1 proved that the United States still dominates the global start-up ecosystem between 2020 and 2021. In 2021, the USA maintained a significant gap between itself and the rest of the world. Therewith, the gap in the overall score slightly decreased between the United States and lower-ranked countries. If one analyses each component in more detail, it is clearly visible in Table 2 that the quantitative component characterizes a downward trend by -0.33, while other components show growth. Thus, the absolute growth rate in 2021 was 1.253.

It is also important to note that according to the Global Start-up Ecosystem Index 2021 (Start-up Blink, 2021), 12 US cities are in the top 30 cities of this rating, and 267 US cities are in the top 1000 (in 2021, 28 new cities appeared in the global ranking). The world leader in innovation is still San Francisco (first place in the rating, 328,996 points), which is home to the world's largest innovation centre, Silicon Valley. US dominance is observed in several industries: e-commerce and retail technology, marketing and sales technology, healthcare, and social and leisure. The global open Internet, the dominance of the English language in the world, opportunities for financing and support from both private and public entities, and immediate access to global markets allow the United States to stay a leading country, according to the Enterprise Development Fund (2022).

Therefore, the analysis of Cluster 1 suggests that the USA is still the land of opportunity, which most vividly represents the world's innovative and breakthrough technological opportunities. Next, the study analysed the ecosystems of the countries included in Cluster 2, which is presented in Table 3.

***Table 3**. Dynamics of changes in start-up ecosystems in Cluster 2 countries*

| Country | Rating change | Quantitative component | Qualitative component | Business environment | Overall summary |
|---|---|---|---|---|---|
| United Kingdom | 0 | 0.99 | 2.95 | 0.37 | 4.313 |
| Israel | 0 | 1.56 | 6.81 | 0 | 8.333 |
| Canada | 0 | 0.25 | 1.8 | 0.11 | 2.156 |
| Germany | 0 | 0.62 | 2.57 | 0.09 | 3.283 |
| Australia | -2 | -0.16 | 2 | 0.01 | 1.855 |
| Sweden | 4 | -0.41 | 4.41 | 0.1 | 4.1 |
| China | 7 | 0.8 | 5.13 | 0.23 | 6.156 |
| Switzerland | 0 | 1.01 | 2.75 | -0.14 | 3.62 |
| Singapore | 6 | 1.5 | 3.97 | -0.28 | 5.176 |
| The Netherlands | -5 | 0.69 | -0.04 | -0.01 | 0.648 |
| France | 0 | 0.83 | 2.62 | 0.22 | 3.67 |
| Estonia | -2 | 0.39 | 1.46 | 0.48 | 2.325 |
| Finland | -1 | 0.43 | 1.6 | 0.24 | 2.278 |
| Spain | **-6** | **0.54** | **-0.49** | **0.27** | **0.325** |
| Lithuania | -1 | 0.49 | 0.38 | 0.52 | 1.376 |
| Russia | 0 | 0.23 | 0.8 | 0.27 | 1.288 |
| Ireland | 0 | 0.32 | 2.35 | 0.33 | -2.997 |

***Source:** compiled by the authors*

Cluster 2 includes 17 leading countries that have moderate both positive and negative changes in rank, including no change in rank. Cluster 2 analysis showed that in 2021, it was Spain that underwent substantial negative changes, which, after leaving the top 10, took the 15th place in the world, i.e., it has a drop in rank by 6 positions. Such negative changes occurred due to a drop in the qualitative component (-0.49), while other components have a slight increase. The Netherlands also has a negative trend, with its rating falling by 5 positions, which was negatively affected by the quality component (-0.04) and the business environment (-0.01). Therewith, the quantitative component and overall result have improved.

A positive trend of +7 positions is occupied by the start-up ecosystem of China, where all components have considerable improvements. Thus, the overall result increased by as much as 6.156. Such a sharp jump speaks of China's transition from a low-tech developing country to an advanced technological powerhouse that should inspire any other country with similar aspirations. Singapore's ecosystem is also showing a positive trend. This country has risen 6 steps from 16th place in the world in 2020 to 10th in 2021. Such a considerable increase in rank demonstrates how fast Singapore's start-up ecosystem is developing. Its start-up ecosystem has a high quantitative and qualitative component, but the business environment has a rather low value and is characterized by a drop (-0.28) compared to most other countries in the top ten (excluding China).

Most of the start-up ecosystems of the world's countries (Great Britain, Israel, Canada, Germany, Switzerland, France, Ireland) stayed in the same place as they were in 2020, but their components have some negative and positive trends. Thus, for instance, Ireland has consistently ranked 18th, the components of its start-up ecosystem are improving, but, with such positive changes, its overall result has a drop of (-2.997). The results of the dynamic analysis of indicators that characterize the country's place in the ranking and the components of its start-up ecosystem according to cluster 3 are presented in Table 4.

***Table 4**. Dynamics of changes in start-up ecosystems in Cluster 3 countries*

| Country | Rating change | Quantitative component | Qualitative component | Business environment | Overall summary |
|---|---|---|---|---|---|
| South Korea | 0 | 0.33 | 1.87 | 0.12 | 2.325 |
| India | 3 | 0.25 | 2.24 | 0.66 | 3.135 |
| Japan | 0 | 0.66 | 2.04 | -0.19 | 2.508 |
| Denmark | 0 | 0.69 | 1.76 | -0.14 | 2.299 |
| Belgium | 1 | 0.82 | 0.95 | -0.04 | 1.727 |
| Brazil | -4 | -0.03 | 0.97 | 0.04 | 0.968 |
| Taiwan | 4 | 0.59 | 0.58 | 0.73 | 1.902 |
| Portugal | 4 | -0.07 | 1.93 | 0.04 | 1.898 |
| Austria | 0 | 0.47 | 1.08 | 0.31 | 1.856 |
| Italy | -4 | 0.17 | 0.67 | 0.21 | 1.045 |
| Poland | -3 | 0.21 | 0.81 | 0.34 | 1.346 |
| Norway | 2 | 0.27 | 1.35 | 0.09 | 1.719 |
| Bulgaria | -3 | -0.11 | 0.05 | 0.37 | 0.31 |
| Chile | -2 | -0.27 | 0.48 | 0.3 | 0.503 |
| Croatia | 2 | -0.16 | 0.86 | 0.29 | 0.984 |
| Mexico | 3 | 0.1 | 0.58 | 0.34 | 1.018 |
| Argentina | -1 | 0.14 | 0.23 | 0.19 | 0.558 |
| Romania | 4 | -0.16 | 0.7 | 0.18 | 0.723 |
| Luxembourg | -3 | 0.27 | 0.23 | -0.41 | 0.09 |
| Turkey | 5 | -0.04 | 0.5 | 0.1 | 0.557 |
| Colombia | -1 | -0.03 | 0.39 | -0.07 | 0.284 |
| South Africa | 4 | 0.16 | 0.52 | -0.04 | 0.622 |
| Thailand | 0 | 0 | 0.15 | -0.01 | 0.133 |
| Philippines | 1 | 0.1 | 0.09 | -0.12 | 0.063 |
| Iceland | 3 | 0.2 | 0.27 | -0.01 | 0.47 |
| Cyprus | -2 | -0.03 | 0.13 | -0.63 | -0.543 |

*Table 4, Continued*

| Country | Rating change | Quantitative component | Qualitative component | Business environment | Overall summary |
|---|---|---|---|---|---|
| North Macedonia | 2 | -0.08 | 0.52 | 0.11 | 0.553 |
| Vietnam | 0 | 0.09 | 0.15 | -0.06 | 0.177 |
| Malta | 1 | 0.28 | 0.09 | 0.05 | 0.411 |
| Kenya | 1 | -0.02 | 0.33 | 0.08 | 0.384 |
| Nigeria | 5 | 0.03 | 0.48 | 0.17 | 0.674 |
| Jordan | 3 | 0.02 | 0.21 | 0.02 | 0.258 |
| Liechtenstein | 1 | 0.13 | 0.06 | -0.02 | 0.165 |
| Lebanon | 0 | 0.09 | 0.02 | -0.11 | 0.006 |
| Jamaica | -3 | 0 | 0.06 | -0.09 | -0.029 |
| Georgia | -1 | 0.01 | 0.05 | -0.06 | 0.001 |
| Ghana | 4 | 0.02 | 0.09 | 0.05 | 0.166 |
| Panama | 4 | 0.04 | 0.05 | 0.05 | 0.138 |
| Qatar | 0 | 0.04 | 0.05 | 0.03 | 0.119 |
| Cape Verde | 4 | 0.1 | 0.03 | 0 | 0.136 |
| Mongolia | 5 | 0.06 | 0.03 | 0.04 | 0.143 |
| Kuwait | 2 | 0 | 0.06 | 0.02 | 0.08 |
| Bangladesh | 5 | 0.04 | 0.06 | 0.04 | 0.132 |
| Somalia | 1 | 0.05 | 0.03 | -0.03 | 0.059 |
| Nepal | 2 | 0.03 | 0.02 | 0.02 | 0.071 |

***Source:*** *compiled by the authors*

The ecosystems of Cluster 3 countries are almost entirely characterized by an increase in absolute value, except for Cyprus (-0.543) and Jamaica (-0.029); as well as positive shifts in the quality component. Downward changes occur in the quantitative component and in the business environment. The countries that had an increase in all components and, accordingly, an increase in the total, also had a negative change in the rating (Argentina, Italy, Poland). An analysis of the dynamics of changes in start-up ecosystems in Cluster 4 countries is presented in Table 5.

***Table 5****. Dynamics of changes in start-up ecosystems in Cluster 4 countries*

| Country | Rating change | Quantitative component | Qualitative component | Business environment | Overall summary |
|---|---|---|---|---|---|
| United Arab Emirates | **-18** | 0.38 | 2.24 | 0.72 | 3.338 |
| New Zealand | -14 | 0.46 | 0.96 | 1.21 | 2.622 |
| Malaysia | -8 | 0.31 | 0.59 | 0.31 | 1.216 |
| Indonesia | -9 | 0.1 | 0.67 | 0.4 | 1.172 |
| Uruguay | -15 | 0.07 | 1.08 | 0.99 | 2.141 |
| Bahrain | -9 | 0.14 | 0.09 | 0.22 | 0.458 |
| Egypt | -11 | 0.1 | 0.22 | 0.21 | 0.535 |
| Saudi Arabia | -17 | 0.18 | 0.15 | 0.33 | 0.655 |
| Pakistan | -7 | 0.01 | 0.07 | 0.05 | 0.136 |
| Kazakhstan | -10 | 0.08 | 0.06 | 0.1 | 0.235 |
| Sri Lanka | -7 | 0.07 | 0.02 | 0.06 | 0.141 |

***Source:*** *compiled by the authors*

The growth of the start-up ecosystems of the countries of the Cluster 4 in 2021 occurred as a result of the improvement of quantitative, qualitative indicators, and business environment indicators. Considering each

of the countries where rapid growth took place separately, today the UAE ranks 2nd in the level of innovation development in the Middle East, and Dubai entered the world's top 50 in terms of innovation software and data and a high concentration of technological innovation. There was also a significant increase in Abu Dhabi, which rose 146 positions in the ranking of 1000 cities of the World Ecosystem Index and ranked 169th. Among the UAE's successful start-ups is the Middle East's first unicorn, Careem, which was sold to Uber for nearly 3 billion USD. Another positive element is the constant reform of business by the government, and the adoption of laws that favour entrepreneurs and the banking system, which ensures the development of innovations (Dymchenko *et al.*, 2022). An analysis of the dynamics of changes in start-up ecosystems in Cluster 5 countries is presented in Table 6.

***Table 6.*** *Dynamics of changes in start-up ecosystems in Cluster 5 countries*

| Country | Rating change | Quantitative component | Qualitative component | Business environment | Overall summary |
|---|---|---|---|---|---|
| Czech Republic | -6 | 0.08 | 0.54 | 0.14 | *0.806* |
| Ukraine. | **-5** | **0.17** | **-0.09** | **0.46** | ***0.648*** |
| Latvia | -6 | 0 | 0.17 | -0.23 | -0.063 |
| Slovenia | -11 | -0.12 | 0.09 | -0.76 | -0.797 |
| Hungary | -12 | 0.06 | 0.03 | -0.76 | -0.659 |
| Serbia | -11 | -0.2 | 0.1 | -0.83 | -0.934 |
| Greece | -10 | -0.18 | 0.09 | -0.94 | -1.023 |
| Slovakia | -5 | -0.05 | 0.08 | -0.9 | -0.876 |
| Peru | -6 | 0.09 | -0.04 | -0.47 | -0.409 |
| Armenia | -8 | -0.15 | 0.07 | -0.67 | -0.751 |
| Belarus | -4 | -0.02 | 0.03 | -0.11 | -0.102 |
| Rwanda | -4 | 0.01 | 0.1 | -0.08 | *0.046* |
| Moldova | -13 | -0.09 | 0.04 | -0.4 | -0.444 |
| Albania | -6 | -0.01 | 0.05 | -0.1 | -0.059 |
| Tunisia | -5 | 0.02 | 0.04 | -0.1 | -0.043 |
| Bosnia and Herzegovina | -12 | -0.04 | 0.04 | -0.15 | -0.149 |
| Ecuador | -15 | -0.03 | 0.01 | -0.16 | -0.183 |
| Azerbaijan | **-19** | **-0.05** | **0.02** | **-0.2** | **-0.23** |
| Paraguay | -11 | -0.03 | 0.04 | -0.1 | -0.107 |
| Morocco | -12 | 0 | 0.03 | -0.05 | -0.036 |
| Dominican Republic | -18 | -0.09 | 0.02 | -0.15 | -0.211 |
| Uganda | -8 | 0 | 0.02 | -0.05 | -0.027 |

***Source:*** *compiled by the authors*

The analysis of Cluster 5 countries shows some ambiguity, despite the only general trend – a considerable drop in the overall ranking of countries (from -5 to -19). Foremost, the Czech Republic should be singled out, which, having a drop of 6 positions in the overall rating, shows an increase in the absolute indicator by 0.806, which is due to the growth of all three components. A similar situation is observed in the start-up ecosystems of two countries of the cluster – Ukraine and Rwanda, which have an absolute growth rate that is due to the growth of two of the three components. Ukraine has an absolute growth of 0.648 due to the growth of the qualitative component (+0.17) and the improvement of the business environment (+0.46) and a slight reduction in the qualitative component (-0.09). All countries of the cluster, except the Czech Republic and Ukraine, show a deterioration in the business environment. Only 5 start-up ecosystems of the cluster countries have an increase in the quantitative component (Czech Republic, Ukraine, Peru, Rwanda, Tunisia) and 3 countries do not have changes in this component (Latvia, Morocco, Uganda). Only two start-up ecosystems of this cluster's countries have a decrease in the quality component – Ukraine and Peru. All other countries show growth according to this indicator.

To assess the impact of changes in each component of the country's start-up ecosystem ($x_1$ – quantitative component; $x_2$ – qualitative component; $x_3$ – business environment) on the change in rating for each cluster, a regression analysis was conducted, the results of which are summarized in Table 7.

***Table 7**. The results of the regression analysis for the start-up ecosystems of the countries of Clusters 2-5*

| Cluster | Model | R | $R^2$ | F |
|---|---|---|---|---|
| 2 | $y = 1.73 - 1.41x_1 - 0.34x_2 + 4.67x_3$ | 0.76275 | 0.58179 | 20.86752 |
| 3 | $y = 40.58 - 9.83x_1 - 14.83x_2 + 10.16x_3$ | 0.36834 | 0.13567 | 6.74993 |
| 4 | $y = -8.41 - 0.14x_1 - 2.31x_2 - 3.89x_3$ | 0.717234 | 0.51442 | 2.47192 |
| 5 | $y = -10.04 + 28.43x_1 + 7.89x_2 - 3.04x_3$ | 0.48585 | 0.23605 | 1.85394 |

***Source:** compiled by the authors*

Table 7 shows that start-up ecosystems of cluster countries have different values of $R$ and $R^2$, which demonstrate a rather low correlation ($R^2$<0.4 is characterized as low). The coefficients near x show different strength and direction of influence on the change rating.

Cluster 2 is the most closely correlated ($R^2$=0.58179), while $x_1$ and $x_2$ are inversely correlated and have a weak effect on y. In Cluster 4, $R^2$=0.5144, and all coefficients have an inverse effect on the change in rating ($y$). Thus, it is recommended for the countries of Cluster 2 to develop the quantitative and qualitative components that, albeit insignificantly (indicators near $x$ have low values), but adversely affect changes in the rating, and to maintain the development of a business environment that has the maximum impact on the change in positions in the rating. For the development of the start-up ecosystems of Cluster 4 countries, it is necessary to develop all components more intensively to ensure the growth of positions in the rating.

Thus, the mathematical models built based on regression-correlation analysis, which describe the influence of the country's start-up ecosystem components on the change in the ranking positions in the section of four clusters demonstrate a strong connection between the factors and the result according to the Chaddock scale (Cluster 2 and 4 with values $R$=0.76275 and $R$=0.717234, respectively); weak connection for start-up ecosystems of Cluster 3 and 5 countries. The latter indicates the dependence of the development of start-up ecosystems on other factors that are not considered in the description of the start-up ecosystem and which affect the development of start-ups and entrepreneurship in the countries of Clusters 3 and 5.

First of all, the proposed clustering of start-up ecosystems of countries has nothing to do with the formation of clusters as a combination of several homogeneous elements that can be considered as a separate unit with certain properties. Groups of countries formed based on clustering have similar characteristics of start-up ecosystems, which can be considered for adopting best practices, forming strategic development documents by the governments of countries to improve individual start-up ecosystems.

Proceeding from the research results of P.T. Roundy and L. Burke-Smalley (2021), the development of entrepreneurial ecosystems should be based on a holistic approach from political institutions (governments of countries) and include: subjects of entrepreneurial activity in the ecosystem; resource providers in the ecosystem; business connections in the ecosystem and the business environment of the ecosystem; development of indicators to find the strengths and weaknesses of individual ecosystems and approaches to measurement.

R. Brown and K. Mason (2017), emphasizing the uniqueness of ecosystems, generally speak about the lack of a standard development strategy. At the same time, the study indicates that there are signs that start-up ecosystems in different countries can be grouped together and have common development vectors. Thus, it can be concluded that the start-up ecosystem of each country is unique, but has common trends that hinder or, on the contrary, help it grow in the current rankings, which allows developing recommendations for improving the ecosystem for a cluster of countries.

The results of this study can be considered to a certain extent as a continuation and substantiation of the prerequisites for the development of entrepreneurial ecosystems (Roundy P.T. and Burke-Smalley, L., 2021) in terms of the intervention of the governments of countries in the formation of a favourable environment, the creation of prerequisites for rapid growth and the provision of general vectors of development individual firms and start-ups. The relevance of this issue is reflected in the set of programs and legal acts aimed at promoting the development of entrepreneurship at various levels – from international to regional. At the international level, according to the European Commission (2022), numerous projects are presented that help start a business in the EU: Start-up Europe (2022), Start-up Europe Partnership (2022), InvestEU Portal (2022). This also includes information on obtaining financing, establishing a European company, taxes on companies in the EU, digitalization of business and sales in the EU.

The work of the Entrepreneurship Development Fund (2022), which helps businesses in cooperation with banks in obtaining financing, was intensified, and the Ukrainian Start-up Fund (2022) was launched. The latest initiative is preconditioned by the fact that start-ups, as a special form of starting one's individual business based on innovative solutions, directly play a substantial role in the development of entrepreneurship. This allows discussing the start-up ecosystem. It is the aforementioned that predetermines the need to investigate the issue of modelling the start-up ecosystem as a prerequisite for increasing entrepreneurial activity.

## CONCLUSIONS

The start-up ecosystem is understood as an interacting and interdependent set of institutions whose activities create an environment for qualitative and quantitative growth of start-ups as subjects of innovative entrepreneurship development. The components of the start-up ecosystem include the environment, qualitative and quantitative characteristics that correlate with the vision of the components in the Global Start-up Ecosystem Index from Start-up Blink.

The use of statistical analysis methods for the data of the countries, which were grouped into 5 clusters, allowed determining the absolute changes in the values of the Global Start-up Ecosystem Index rating indicators from Start-up Blink: rating change, quantitative component, qualitative component, business environment, general summary. In Cluster 1, the United States is a single country, and the position of its ecosystem is characterized by leadership and a considerable gap from others. The start-up ecosystem of almost all countries in Cluster 2 demonstrate positive dynamic shifts in all components, which lead to the growth of the overall result. Ecosystems of Cluster 3 countries are almost completely described by the growth of the overall total, which is entirely conditioned upon the growth of the qualitative component with various dynamic changes in other components of the country's ecosystem, which leads to positive shifts in the rating. The ecosystems of Cluster 4 countries are described by the growth of all components of the ecosystem, but insufficient to change their positions in the rating. Ecosystems of Cluster 5 countries have a drop in the rating with an increase in the qualitative component and a reduction in other components.

Mathematical models built based on regression-correlation analysis, which describe the influence of the components of the country's ecosystem on the change in the ranking positions in four clusters demonstrate: a strong connection between factors and the result (Clusters 2, 4); weak connection for countries in Cluster 3, 5. The latter testifies to the dependence of the development of start-up ecosystems on other factors that are not considered in their description and which affect the development of start-ups and entrepreneurship in countries of Cluster 3, 5. These results are the basis for developing recommendations, start-ups and plans for the development of start-up ecosystems at the national and regional levels as prerequisites for the activation of entrepreneurial activity.

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## Моделювання впливу складових стартап екосистеми: підприємницький аспект

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**Анотація**. Визначення засад розвитку стартап екосистем країни як основи активізації підприємництва є нагальним завданням відбудови економіки країни. Мета роботи полягає у визначення шляхів покращення стартап екосистеми країни на основі побудови економіко-математичних моделей для активізації підприємницької діяльності. В основу методології дослідження покладено статистичні методи дослідження, а саме: аналіз динаміки; для оцінки сили впливу кожної компоненти стартап екосистеми на зміну позиції в рейтингу було обрано регресійно-кореляційний аналіз, який дозволяє виявити силу впливу факторів на кінцевий показник. Досліджено складові екосистеми стартапів, під якою розуміється взаємодіюча та взаємозалежна сукупність інституцій, діяльність яких створює середовище для якісного та кількісного зростання стартапів як суб'єктів інноваційного розвитку підприємництва; використання методів статистичного аналізу до даних країн, які було згруповано в 5 кластерів, дозволило визначити абсолютні зміни величин показників рейтингу Global Startup Ecosystem Index від StartupBlink: зміна рейтингу, кількісна складова, якісна складова, бізнес середовище, загальний підсумок; побудовано на основі регресійно-кореляційного аналізу економіко-математичні моделі, які описують вплив складових екосистеми країни на зміну позицій рейтингу в розрізі чотирьох кластерів демонструють: сильний зв'язок між факторами та результатом (кластери 2, 4); слабкий зв'язок для країн кластеру 3,5, останнє свідчить про залежність розвитку стартап екосистем від інших факторів, які не враховані в їх описі та які впливають на розвиток стартапів та підприємництва в країнах кластерів 3, 5. Практична цінність роботи полягає в тому, що результати роботи є базисом для формування стратегій розвитку стартап екосистем на національному та регіональному рівні органами місцевої та державної влади

**Ключові слова**: стартап, екосистема країни, економіко-математична модель, підприємництво, рейтинг