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Conditions and Results of Innovative Development in Latin America and Russia: A Comparative Analysis

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ABSTRACT

Relevance. The problems of innovative development and effective innovation management have long been a priority in the world economy and, most likely, their relevance will be in the mainstream for many years to come. The paper analyses the provision and performance of innovation processes in nine countries of Latin America and Russia in **order** to identify the most successful economies in terms of approaches and effects of innovation activity in different evaluation planes. The specifics of structural efficiency of innovation activity components in crisis and post-crisis periods have been studied. **Research methods** — comparative analysis of the structure of the global innovation index (GII) in the target countries in 2020 and 2023, multiple regression analysis of the impact of resources and innovation results on the level of the global innovation index, t-statistics to compare the innovation dynamics of the target countries in the period from 2020 to 2023. **Scientific novelty** — on the basis of statistical approach the specifics of innovative development of Latin American countries and Russia and regularities of achieving different levels of the global innovation index in the crisis and post-crisis periods are revealed. **The results of the study** show that the leaders in terms of GII level among Latin American countries are Brazil, Chile, Uruguay, Colombia and Argentina, and the most important for the formation of GII are the components of innovation results — the development of technology and knowledge economy, as well as the results of creative activity. Ecuador and Peru are the countries with the most detached innovation development trajectory. In the year of the covid crisis the components of institutions and market development were particularly developed, in the post-covid year — the level of business development, as well as human capital and research. Finally, the dynamics of GII in Russia is closest to Brazil in most components. The results obtained are of **practical value** as a reference point in the development and adoption of economic and political decisions on the reallocation and concentration of resources for the development of the most effective components of GII.

Keywords: innovation; innovative development; innovation management; global innovation index; innovation resources; innovation results; Latin America; crisis; comparative analysis; regression analysis

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INTRODUCTION

Innovation in the management of both the state and corporations is a necessary condition for socio-economic development. For more than 20 years, scientific literature has referred to it as a fundamental driver of growth [1, 2]. However, this concept is so broad and ambiguous that it is often perceived as a call to action rather than a strict requirement for improving efficiency. But what is the structure of innovation? How significant are its components, and are they equally important?

We will address these questions using the example of Latin American countries and Russia.

Why did we choose Latin America?

Firstly, the countries in this region exhibit significant differences in their levels of innovation development.

Secondly, they are geographically close to one another, allowing us to disregard physical factors that could significantly impact the conditions and outcomes of innovation activities.

Thirdly, these countries share certain similarities with Russia.

Fourth, there is a noticeable gap in scientific literature concerning developing countries.

The wealth of natural resources and cultural heritage is considered the primary driver of innovation in Latin American and Caribbean countries [3]. In particular, research and development efforts are often focused on the mining industry [4], transportation logistics, and related infrastructure [5]. At the same time, there are also advancements in renewable energy and environmental sustainability.[1] A key reason for the lag in other sectors is the extractive nature of institutions, which prevents economies from moving beyond traditional business models [6, 7]. One study also highlights high levels of social inequality and poverty as major barriers to innovation [8]. As a result, researchers recommend measuring innovation indicators at the country level and conducting longitudinal analyses of the most successful nations in terms of innovation and sustainable development.

Some studies attempt to compare innovation characteristics across different countries, including those in Latin America. For example, when examining the Asia-Pacific and Latin American regions, scholars have noted that despite similar income levels, their growth strategies differ: the former prioritizes export-oriented development, while the latter relies on import-substitution technologies and domestic markets. However, in both cases, innovation remains a crucial factor for economic growth and macroeconomic stability [9]. Patent activity is often cited as the primary outcome of innovation, though its direct impact on a country's technological and economic efficiency remains ambiguous.

Other researchers have found that in six Latin American countries, the conditions for investing in innovation are far more heterogeneous than in member states of the Organization for Economic Co-operation and Development (OECD) [10]. Consequently, accurately predicting the conditions under which investment in innovation becomes reliable remains a significant challenge.

When considering the prospects for cooperation between the European Union and Latin America, one of the stated goals is to strengthen best practices and enhance the EU's attractiveness in research and innovation, as well as its financial and industrial competitiveness [11]. At the same time, the authors identify addressing environmental issues as a primary objective for developing countries. They also highlight the significant disparities in R&D funding across Latin American and Caribbean nations and propose joint programs to support scientific research and academic mobility as a means of leveling these differences.

It should be acknowledged that innovation development is not a top priority for Latin American countries — the main drivers of social and economic development in the region are identified as institutional factors [12]. Additionally,

[1] URL: https://www.scidev.net/america-latina/news/chile-comienza-a-revertir-baja-inversion-en-ciencia-y-tecnologia/

the region demonstrates relatively weak patent activity [13].

Notably, there is a lack of comparative studies examining innovation dynamics in Latin American countries and Russia. In particular, D.S. Bezhko points out that these economies are only beginning to enter the post-industrial phase and therefore require unique development trajectories. The study identifies similar innovation development tools in both regions, such as technology parks. However, in Latin America, their creation is primarily driven by private investors, whereas in Russia, it is predominantly initiated by the state [14].

DATA AND METHODS

The primary information base for this study consists of publicly available data on the Global Innovation Index (GII) for 2020 and 2023, with the main source being reports from the World Intellectual Property Organization[2] (WIPO). The research focuses on comparing differences between the crisis year (2020) and the post-crisis year (2023).

The Global Innovation Index has been published since 2007 by WIPO in collaboration with the Network of Academic Partners. It includes 80 indicators grouped into seven categories, covering 132 countries.

This study utilizes quantitative GII values for Russia and Latin American countries (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay), along with data on innovation resources and outcomes, as well as detailed breakdowns of these metrics.

The key components of the GII are calculated as the average of two sub-indices, each of which is based on multiple aggregated components (aggregates):

- innovation resources, [aggregates: institutions (Ins), human capital and research (HCR), infrastructure (Infr), market sophistication (MS), business sophistication (BS)];
- innovation output, [aggregates: knowledge and technology outputs (KTO), creative outputs (CO)].

To determine the significance of GII aggregates in shaping the final indicator, a multiple regression analysis was conducted using a model of the following type:

$$y = b_0 + b_1x_1 + b_2x_2 + \ldots + b_ix_i + \varepsilon, \quad (1)$$

where y is the dependent (explained) variable, the Global Innovation Index; x_1, x_2...x_i are the independent variables representing the GII aggregates; b_0 is the intercept; b_1, b_2...b_i are the regression coefficients; I is the number of independent variables; ε is the random error (deviation).

This method allows us to determine the degree of influence that each selected predictor and their combination has on the formation of the dependent variable. Its advantage over alternative approaches lies in the relatively simple assessment of model reliability through tests for multicollinearity and the variance inflation factor (VIF). Additionally, the adjusted coefficient of determination helps establish how much the dependent variable depends on the set of selected regressors.

To compare countries across different years in terms of GII aggregate dynamics, t-statistics were calculated for independent variables.[3] Differences between Latin American countries were assessed separately, followed by a comparison between Russia and each of them. This approach provided insights into which countries exhibit minimal differences and which follow unique innovation trajectories.

[2] URL: https://www.wipo.int/ru/web/global-innovation-index

[3] The calculations were made based on the sources: URL: https://www.wipo.int/documents/d/global-innovation-index/docs-en-2020-wipo_pub_gii_2020.pdf; https://www.wipo.int/documents/d/global-innovation-index/docs-en-2021-wipo_pub_gii_2021.pdf; https://www.wipo.int/documents/d/global-innovation-index/docs-en-wipo-pub-2000–2022-en-main-report-global-innovation-index-2022–15th-edition.pdf; https://www.wipo.int/edocs/pubdocs/en/wipo-pub-2000–2023-section5-en-gii-2023-economy-profiles-global-innovation-index-2023–16th-edition.pdf

For a clear representation of GII aggregates and related indicators, graphical and comparative analysis methods were employed. These methods have proven effective in previous comparative tests of innovation dynamics in individual countries [15].

The key questions of the analysis are as follows:

1. Which countries are the most successful in terms of innovation and innovation resource management?

2. Which countries deviate the most in innovation development dynamics from the top-performing ones?

3. Which innovation factors should be prioritized to achieve the best results?

RESULTS AND DISCUSSION

The ability of the multiple regression econometric model to explain the dependence of the Global Innovation Index (GII) on its individual aggregates is logical since the index itself is calculated based on these components. However, the presented models (2) and (3) allow us to assess the degree of impact that each individual aggregate had on GII in 2020 and 2023.

2020:

$$GII_{2020} = -0,06 + 0,098 \times Ins + 0,1 \times HCR + \\ + 0,1 \times Infr + 0,1 \times MS + 0,1 \times BS + 0,25 \times \\ \times KTO + 0,26 \times CO; \quad (2)$$

2023:

$$GII_{2023} = -0,29 + 0,098 \times Ins + 0,1 \times HCR + 0,11 \times \\ \times Infr + 0,102 \times MS + 0,093 \times BS + 0,25 \times KTO + \\ + 0,252 \times CO, \quad (3)$$

where: *GII* is Global Innovation Index for 2020 and 2023, respectively; *Ins* is–Institutions aggregate; *HCR* is Human Capital and Research aggregate; *Infr* is Infrastructure aggregate; *MS* is Market Sophistication aggregate; *BS* is Business Sophistication aggregate; *KTO* is Knowledge and Technology Outputs aggregate; *CO* is Creative Outputs aggregate.

Validation tests confirm the reliability of the models: for model (2): F-statistic (Fisher's criterion) = 115.494.4, p-value (confidence level) = 0.0023, R^2 (coefficient of determination) = 0.99999876, R^2_{corr} (adjusted coefficient of determination) = 0.9999901, for model (3): F-statistic = 95,955.09, p-value = 0.0025, R^2 = 0.99999851, R^2_{corr} = 0.99998809.

These results are further confirmed by multicollinearity tests and variance inflation factor (VIF) analysis.

Let's pay attention to the coefficients linked to different regressors. Thus, the regression coefficients show that the most significant impact on the final GII score comes from the Creative Outputs (CO) aggregate, with coefficients of 0.26 in 2020 and 0.252 in 2023, as well as Knowledge and Technology Outputs (KTO), which remains at 0.25 for both years. These findings align with the nature of these aggregates, which reflect innovation performance and naturally have the highest coefficients. The slightly higher CO coefficient in 2020 is likely due to the increased demand for creative industry products during the pandemic-induced isolation [16, 17].

The impact of innovation resources on the overall GII remained relatively equal across both years, with minor variability in 2023, possibly due to the broader opportunities for innovation development during this period.

Graphical relationships between the aggregate values of innovation results and GII in Latin American countries and Russia are presented in *Fig. 1*.

According to observations:

1. Chile had the highest GII in 2020, while Brazil led in 2023. Uruguay, Colombia, and Argentina followed closely behind.

2. Innovation performance improved in almost all countries by 2023.

3. The most significant growth in innovation outputs was observed in Brazil, Chile, and Argentina.

4. In 2020, KTO exceeded CO only in Brazil. By 2023, this trend extended to Colombia

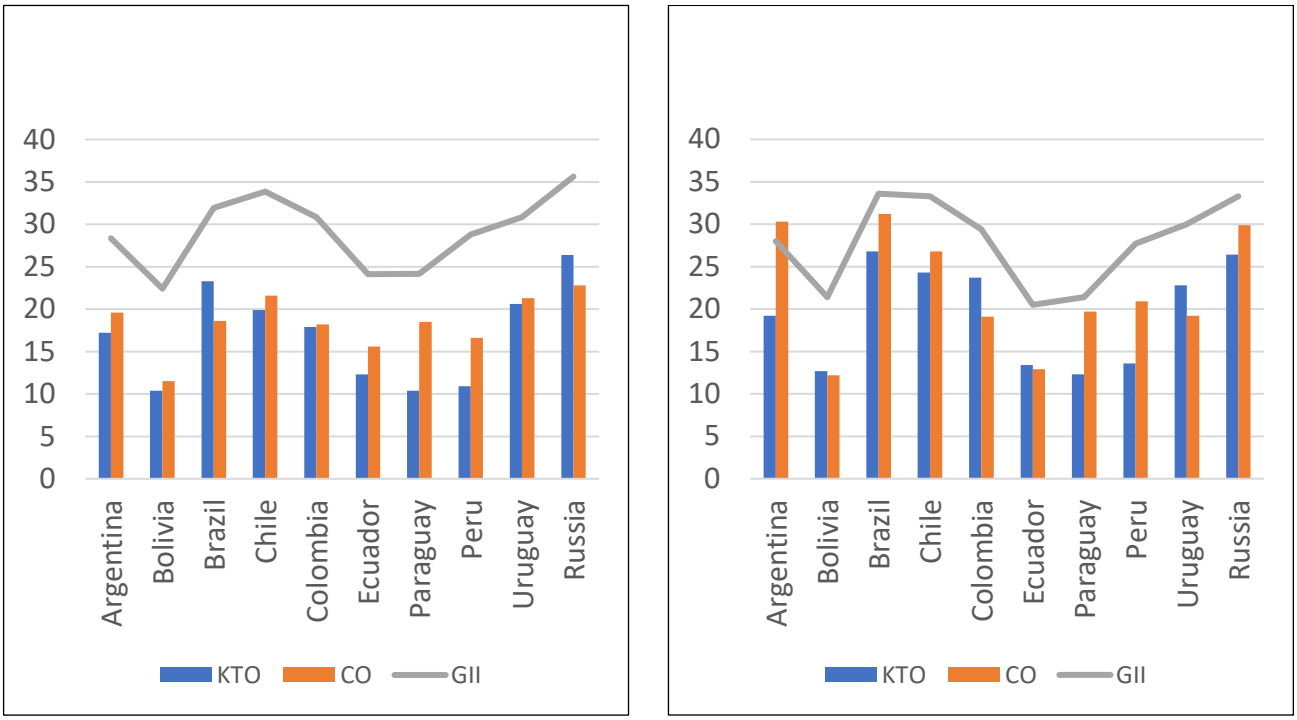

Fig. 1. **Ratio of GII levels in Latin American countries and Russia to KTO and CO aggregates in 2020 (left) and 2023 (right), in points**

KTO – knowledge and technology outputs, CO – creative outputs, GII – Global Innovation Index.

Source: compiled by the author on the basis of data: URL: https://www.wipo.int/documents/d/global-innovation-index/docs-en-2020-wipo_pub_gii_2020.pdf; https://www.wipo.int/edocs/pubdocs/en/wipo-pub-2000-2023-section5-en-gii-2023-economy-profiles-global-innovation-index-2023-16th-edition.pdf

and Uruguay, indicating a post-crisis push for knowledge-based economies and technological innovation.

The relationship between the innovation performance components of the GII in Russia for both years is most similar to the situation in Brazil. It should be noted, however, that the absolute values of the innovation performance components and the overall index in 2020 in Russia were higher than in any of the Latin American countries considered, while in 2023, Brazil led. Thus, the opinion about the global similarity between Russia and the countries in this region in cultural and mental aspects is confirmed [18].

According to the Latin American country sample, pairwise comparisons of the data series reflecting the dynamics of aggregated innovation performance results between 2020 and 2023, along with the corresponding calculation of *t*-statistics for independent variables, showed the following:

1. The most noticeable individual dynamics of innovation results (both *KTO* and *CO*) were observed in Ecuador, with differences from Argentina, Brazil, Chile, and Colombia. Specifically, for *KTO*, differences were found with Uruguay, and for *CO*, with Paraguay and Peru. This is due to the slight overall growth in *KTO* and the decline in *CO* in Ecuador compared to the aforementioned countries. Moreover, the most negative dynamics in the *KTO* aggregate were observed in the "creative knowledge" and "knowledge dissemination" groups, with only a slight growth in "knowledge impact." In turn, a significant decline in the CO aggregate occurred in the "intangible assets" and "creative goods

and services" groups, with a noticeable increase in "online creativity."

2. A high degree of individuality was identified in Peru: significant differences were found with Chile in both *KTO* and *CO*; separately for *KTO* — with Argentina, Brazil, Colombia, and Uruguay; for *CO* — with Ecuador. A detailed analysis showed a more favorable situation in Peru compared to Ecuador: positive dynamics were observed in all KTO indicator groups, with the highest growth in the "knowledge impact" group; the overall CO aggregate dynamics were also positive, with significant growth in the "intangible assets" and "online creativity" groups, alongside a sharp decline in "creative goods and services."

3. Countries where no differences were found in any innovation performance component: Argentina and Colombia, Colombia and Uruguay, Brazil and Chile, Chile and Uruguay, Paraguay and Peru. This is explained by the similar dynamics of innovation performance indicators in the named pairs. Sometimes, no differences between the two countries are observed, as in the case of the uniform growth of KTO indicators in Argentina and Colombia, Colombia and Uruguay, or due to alternating periods of growth and decline, as in Brazil and Chile, Paraguay and Peru.

The use of *t*-statistics to compare Latin American countries and Russia revealed the following.

1. In the dynamics of innovation results, both *KTO* and *CO*, no significant differences were found between Brazil and Russia. In 2023, Russia remained at the same level, while Brazil experienced a slight increase, which was statistically insignificant for conclusions about differences between the countries. However, in the structure of both countries' aggregates, there were both increases (in the "knowledge impact" group, a positive dynamic of the "high-tech production" indicator was observed) and setbacks ("knowledge dissemination"). Furthermore, a significant growth in the overall *CO* aggregate value was noted both in the Russian Federation (from 22.8 in 2020 to 29.9 in 2023) and in Brazil (from 18.6 to 31.2, respectively), primarily due to the positive dynamics in the "intangible assets" and "online creativity" groups.

2. For other countries in the region, differences in the dynamics of *KTO* were observed with Russia.

3. For the *CO* aggregate, no differences were found between Argentina and Russia, Chile and Russia, Paraguay and Russia, and Uruguay and Russia. This confirms their significant similarity in the areas of creative activity and aligns with previous conclusions about the creative economy in Latin America as a new vector for the development of foreign trade relations [19].

Next, we will analyze the relationships between the aggregate values of innovation resources and GII in the Latin American countries and Russia (*Fig. 2*).

Analysis of the presented diagrams allows for the following conclusions:

1. The levels of innovation resources across countries in 2020 and 2023 differ.

2. There was a significant (sometimes more than twice) decrease in the levels of the *Ins* and *MS* components in all countries, with a few exceptions. The most negative dynamics were observed in Argentina (a decrease of 43.1% for *Ins* and 27.2% for *MS*), Brazil (a decrease of 34.2% for *Ins* and 10.8% for *MS*), Paraguay (a decrease of 33.7% for *Ins* and 25.3% for *MS*), Colombia (a decrease of 28.3% for *Ins* and 34.8% for *MS*), etc.

3. Variable dynamics were observed for the *HCR* and *Infr* components, with the most significant decline in *HCR* seen in Paraguay (46%) and Argentina (16.4%).

4. The most positive dynamics were observed in the *BS* component, especially in Uruguay (32.1%) and Colombia (25.2%).

The analysis of *t*-statistics for independent variables comparing the dynamics of innovation resources in Latin American countries showed the following:

1. Significant differences in all five innovation resource aggregates were confirmed between Uruguay and Brazil, as well as between Uruguay and Peru. It should be noted that the differences

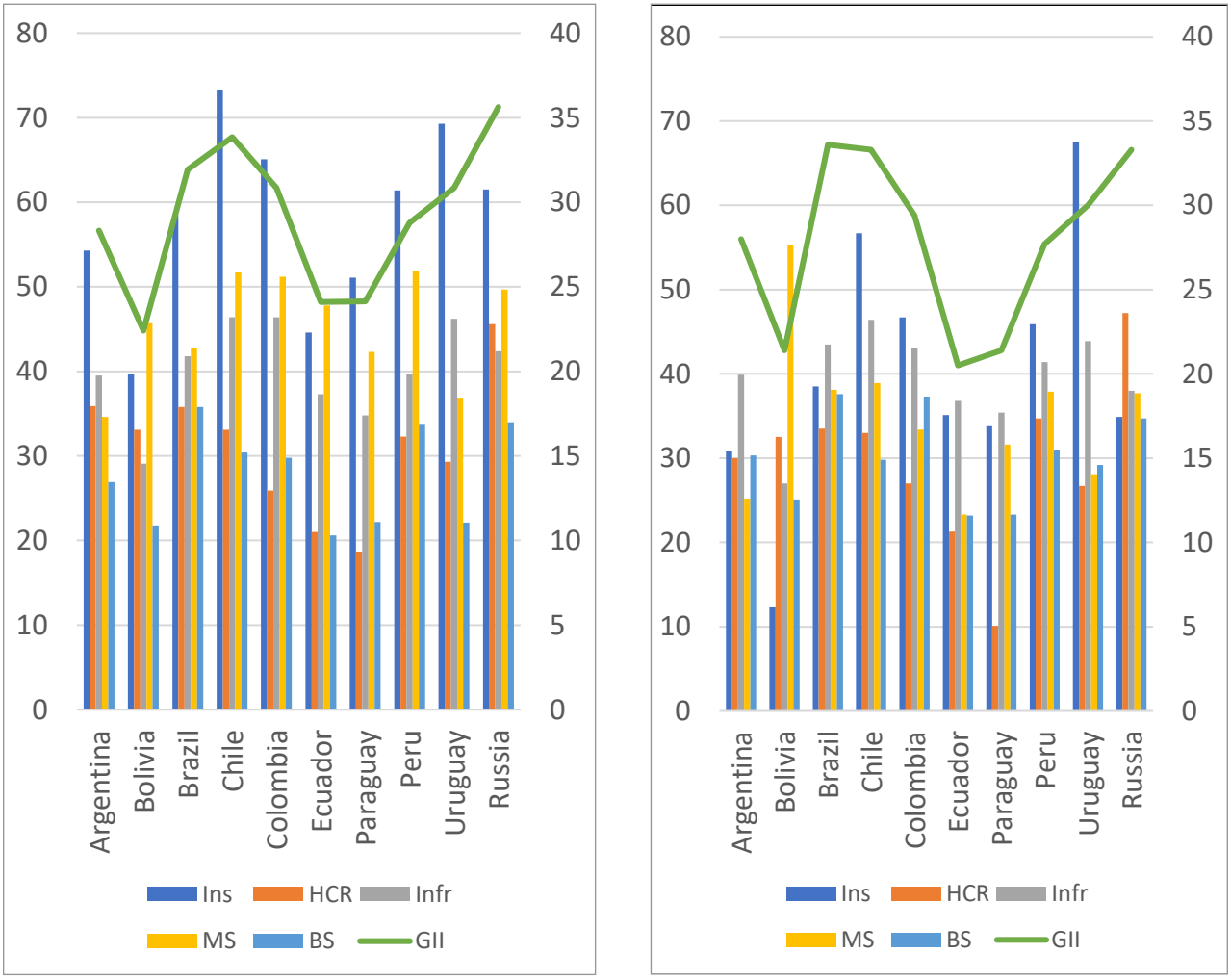

Fig. 2. **Ratio of Latin American and Russian GII levels with Ins, HCR, Infr, MS, BS aggregates in 2020 (left) and 2023 (right), in points**

Ins — institutions, HCR — human capital and research, Infr — infrastructure, MS — market sophistication, BS — business sophistication, GII — Global Innovation Index.

Source: compiled by the author on the basis of data: URL: https://www.wipo.int/documents/d/global-innovation-index/docs-en-2020-wipo_pub_gii_2020.pdf; https://www.wipo.int/edocs/pubdocs/en/wipo-pub-2000–2023-section5-en-gii-2023-economy-profiles-global-innovation-index-2023–16th-edition.pdf

in favor of Uruguay are explained by a substantial decline in a number of GII aggregates in Brazil and Peru. These findings are confirmed by the economic monitoring results of Brazil and Uruguay conducted by the Economic Development Advisory Council of the Catholic University of Uruguay.[4]

2. Differences were found in four aggregates (except *MS*) between Ecuador and Chile, Ecuador and Colombia, and Paraguay and Chile. The reasons lie in statistical calculations: either due to varying degrees of decline, often depending on the base values of 2020 (as in the case of Ecuador and Chile, Paraguay and Chile), or due to the different nature of dynamics [uniform dynamics does not coincide with volatile indicators (Ecuador and Colombia)].

3. The differences are minimal (no more than two aggregates) between Argentina — on the one hand, and Brazil (*MS* and *BS*), Colombia (*HCR* and *Infr*), Ecuador (*HCR* and *BS*), Paraguay (*HCR* and

[4] URL: https://sudamerica.ru/uruguay/kak-ehkonomicheskaya-aktivnost-urugvaya-sootnositsya-s-argentinoj-i-braziliej

BS), Peru (*MS* and *BS*), Uruguay (*Ins* and *BS*) — on the other hand.

In turn, the study of *t*-statistics for Latin American countries and Russia in order to compare them showed the following:

1. For the *Ins* aggregate, no significant differences were found between Russia and all countries in the region. Here the decline in the values of this aggregate in all the studied countries is worth noting: a significant decrease was observed in the groups "political environment" and (especially) "business environment" in Argentina, Brazil, Colombia, Chile, Peru, Paraguay, and Russia. A less noticeable decline was observed in the "legal framework" group.

2. For the *HCR* aggregate, in contrast, differences were found between Russia and all the countries in the region. A slight increase in the total value of the aggregate was observed for Russia due to growth in the values of the "general education" and "R&D" groups, and a slight decrease in "higher education."

3. For the *Infr* aggregate, differences were found between Russia — on the one hand, and Chile, Colombia, and Uruguay — on the other. The negative dynamics of the total values of this aggregate in Russia were associated with a slight decrease in the values of the "information and communication technologies," "general infrastructure," and a more significant decline in "environmental sustainability" groups. In the comparable Latin American countries, the dynamics were not so unambiguous.

4. For the MS aggregate, differences were found between Russia — on the one hand, and Argentina and Uruguay — on the other. The latter demonstrated negative dynamics in all three structural groups of indicators: "credit," "investments," and "trade, competition, and market size"; in Russia, there was growth in the last group, although a decline was observed in the first two.

5. For the *BS* aggregate, no differences were found between Russia and Colombia, which likely reflects the predominantly positive dynamics of indicator values for this aggregate across all three groups: "knowledge workers," "innovation linkages," and "knowledge absorption."

In previous works, the author proposed approaches to building innovation systems and forming a knowledge economy [20, 21]. Now, based on the analysis, we will formulate generalized recommendations based on statistically confirmed similarities and differences between countries in the field of innovation dynamics, which may serve as directions for further research.

1. The government of Ecuador should conduct a comprehensive analysis of the specifics of managing innovation processes in Brazil and Chile (primarily), Argentina and Colombia, as well as thoroughly study the scientific and technological performance of Uruguay.

2. The government of Peru should comprehensively study the specifics of managing innovation processes in Chile and conduct a detailed analysis of the scientific and technological performance of Brazil, Argentina, Colombia, and Uruguay.

3. The governments of Brazil, Chile, Argentina, Uruguay, and Colombia should collaborate on the development and implementation of innovation policies, which would activate the introduction of innovations into the economies of these countries.

4. The government of Russia should initiate and support domestic research on the dynamics of innovation activity and performance in Brazil, as well as, in certain areas, Argentina, Chile, Paraguay, and Uruguay, due to the similarities in the development of innovation activities and results. The tasks of such work will be, on one hand, to identify the factors that accelerate or, conversely, hinder innovation development, and on the other hand, to determine the conditions and prerequisites for increasing innovation activity.

CONCLUSION

There are studies that identify a consistent sequence where first, the socio-economic develop-

ment of a country creates the conditions for the formation of innovations, and then these innovations significantly influence the development of society [22, 23]. The purpose of the comparative analysis between countries is to identify leading, stagnating, and lagging states, as well as to determine the causes of the observed dynamics.

Comparing countries with similar conditions of existence and development allows us to focus on a specific research subject and, accordingly, more accurately identify the causes of a given situation, develop scenarios, and mechanisms for its positive changes.

The main conclusions of this work are as follows:

1. Developing countries (including Latin American states), unlike developed ones (mostly European countries and the USA), are rarely subject to analysis of innovation activity and dynamics. At the same time, the innovativeness of each country in the region is different: both in general — based on the set of indicators within the *GII* — and across individual groups of innovation aggregates.

2. The leaders in terms of *GII* among Latin American countries are Brazil, Chile, Uruguay, Colombia, and Argentina.

3. The most important components for the formation of the *GII* are the results of innovation: the development of technology and the knowledge economy, and creative activities.

4. The most distinct innovation development trajectory is observed in Ecuador and Peru.

5. In 2020, particular attention was given to the components of institutions and market development, while in 2023, the focus shifted to business, as well as human capital and research.

6. The Russian Federation, in terms of economic development and innovation activity, is quite similar to the countries of the studied region. The dynamics of *GII* in Russia for most components is most similar to Brazil. At the same time, in terms of indicators that characterize the use of knowledge and technology, Russia differs from the other countries, while for those defining creative outcomes, it is similar to four other countries.

The results of the work have some limitations, related to certain calculation errors of the global innovation index and the occasional lack of data, which sometimes necessitates trend-based assessments of specific indicators across years. Nevertheless, the development of this topic is promising due to its high expected impact in both global and national contexts.

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