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# NATIONAL INNOVATION SYSTEMS: CLASSIFICATION, RANKING AND POSITIONING IN THE GLOBAL INNOVATION SPACE

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The practical relevance of comparative research of National Innovation Systems (NIS) is substantiated. Classification features and manifestations of the specific national models of NIS are concretized. Methods of positioning NIS of Ukraine in the global and regional (European) Innovation Space are presented and realized.

***Keywords:*** innovation, national innovation system, a national model, classification features, typology, technology pyramid, innovation center, innovative periphery.

**Statement of problem.** Long-term preservation of regressive trends in the national economy shows that the discretionary stabilizing measures that are deprived of innovative component, are not able to terminate primitivization of technological structure and slow down the drift of Ukraine towards the periphery of the global economy. There is no doubt that an effective patriotic national innovation system (NIS) should play a key role in the solution of changing the vector of macroeconomic dynamics and in the overcoming existing socio-economic tribulations.

**Analysis of recent papers.** Innovation imperative of national economic development advances innovative problems to the forefront of the latest scientific research. A significant research segment is occupied by the development which focuses on the problems of creation and effective regulation of national innovation systems, their monitoring and diagnostics. Among them special scientific and practical value inherent in the works of B. Amable, Yu. Bazhal, H. Chesbrough, J. Howe, H. Etzkowitz & L. Leydesdorff, L. Fedulova, C. Freeman, P. Gloor, T. Grosfeld , N. Ivanova, C. Perez, M. Porter, V. Polterovich, R. Rothwell, M. Voynarenko and etc.

It should be recognized that despite the good results, many questions still remain debatable and unresolved. First of all, it is about extremely actual in the practical terms the comparative research of NIS in the context of trialectic of general, special and singular. Apart from focusing on the national specifics of the innovation dynamics, they, on the one hand, help to identify the absolute (monopolistic) and relative (comparative) competitive advantages of domestic NIS and improve the quality of SWOT-analysis. On the other hand, thanks to these studies the filtering and borrowing of foreign experience in regulating of innovative activity by the criterion of its adequacy to the domestic economic realities and national project of NIS significantly simplifies. And, finally, the probability of inefficient decision-making decreases under the conditions of well-known absence of accumulated personal experience concerning decent answers to innovation challenges of global competition.

**Aim of the paper** are comparative research and classification of NIS's models, revelation of the method for positioning of NIS in global and regional (European) innovation space.

**Materials and methods.** Starting with B-A. Lundvall (1992) and C. Freeman (1995) [1-2] who were the founders of the concept of national innovation systems, a point of view on the NIS as on the interactive and self-reproducing system (macro-institute, cluster) that ensures coordination and cooperation of economic actors are involved in the processes of generation, diffusion and commercialization of knowledge and innovation, was established in professional literature.

The mission of the NIS is in the formation and development of endogenous innovation levers of socio-economic development, improving public welfare, competitiveness of the national economy and protection its movement in the global political and economic process. The complementary aims are:

- creating a favourable environment for activation the innovative activity of economic actors (subjects) and increasing its effectiveness;
- expanded reproduction scientific and technical and innovation potential of the national economy, finding the public consensus regarding directions and methods of theirs strengthening and updating;
- building up the system of development institutions and creating an effective mechanism of their financing;
- investment support of strategic priorities of innovation development of the country;
- integration into the global scientific, technological and innovation space, with raising the country's position on the global market of objects of the intellectual property and high-technology, improving its innovative image, increasing appropriation of global intellectual and technological rent by its residents, etc.

The involvement of NIS in the national ontogenesis particularly bright evident when considering the many interrelated determinants under the influence of which it is evolutionarily formed and developed. The main ones are:

- territorial dimensions of the national economy, previously gained its self-development capacity, available resource, technological and market capabilities (human and financial capital, scientific and technical potential, technological readiness, business sophistication, goods market efficiency, higher education and training, etc. [3–5]);
- laid down value-targets priorities of public choice in the past;
- directions of specialization and place in the international division of scientific and technical labour, vector and stable long-term trend of changes in country's R&D-activity and its multidimensional technological profile (fig. 1).

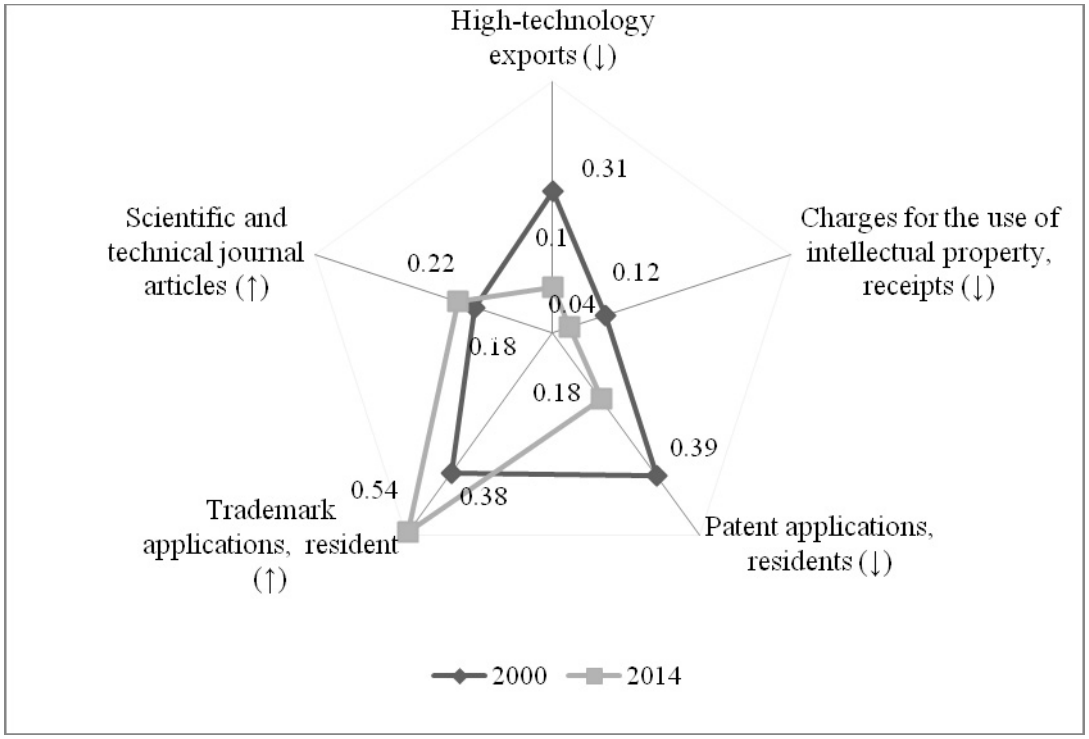


Figure 1. Ukraine's share (as % of world total volume) in the global market high-tech products, in international R&D activity and the distribution of its results («R&D and technological profile of Ukraine») [developed by authors with using [6]]

- positioning of NIS in the global «technological pyramid» (fig. 2). How to de-

cide on which level of the pyramid is located a particular country? It is logical to assume that the appropriate conclusions should be made in view of the country's participation in the processes of creation, redistribution and appropriation of global innovation rent. Foremost, analysis and comparison should be made on the basis of statistical indicators such as «Charges for the use of intellectual property, receipts (Balance of Payment, current US$)» and «High-technology exports (current US$)» [6]. The first indicator reflects the size of the intellectual component of innovation rent, the second gives an approximate estimate of the technological component's size. Clearly, the dependence of a country' status position of the country and its assigned share of global innovation rent is straight (Table 1).

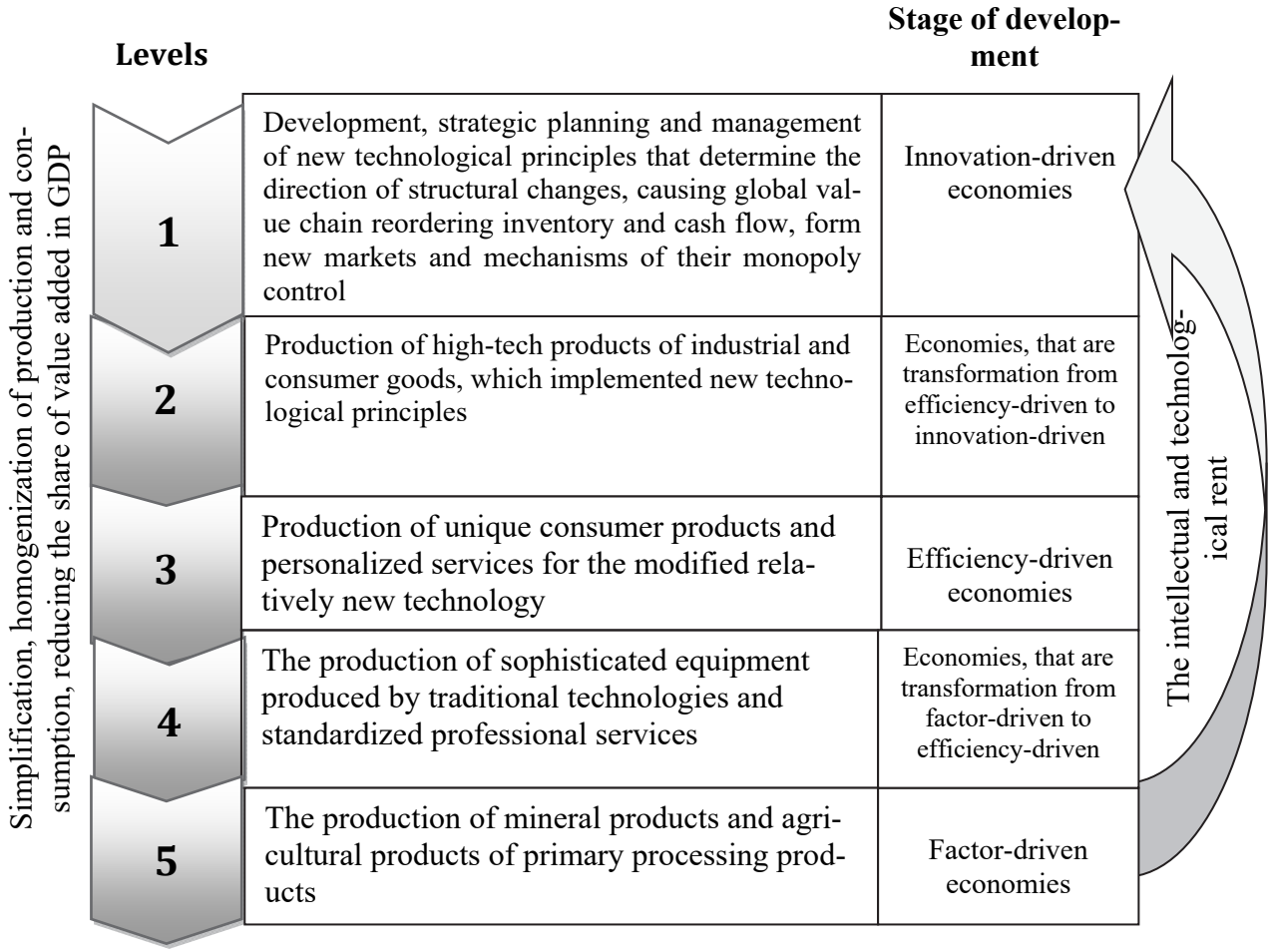


Figure 2. Technological Pyramid (production cut) [developed by authors]

- available integration alternatives and evolutionary perspectives within the selected integration model;
- the degree and nature of internal opening economic space, the degree of protection of its innovation sphere, the fullness of the cycle of reproduction of knowledge and innovations;
- features of the historical development of state institutions and forms entrepreneurship, traditions of public-private partnership and the relationship between the center and regions;
- generally accepted principles of self-organization of open macroeconomic space (liberalism and conservatism, individualism and collectivism, power distance, hierarchy, synarchy, anarchy, autarky and cosmopolitanism, tolerance and heterophobia, protectionism and free trade, etc.);
- degrees of freedom and the patterns of behavior of microeconomic entities, adequate to diverse challenges of the environment and the bifurcation zones and etc.

From the system analysis theory are known both the dialectical interdependence of

functions and structure of systems, and the requirements to their adequacy. The structure must conform to the logic of the system, make it possible the implementing its strategic mission and execution the functional purpose under the certain limitations and criteria of effectiveness. This is also true in relation to the NIS. A set of its components is typical [8], dynamic and relevant, but not rigidly fixed.

Table 1

Separation of intellectual and technological rent by groups of countries, 2015

| | Classification of countries by stage of development | Number of economies | Charges for the use of intellectual property, as share (%) of world total receipts | High-technology exports, as share (%) of world total export |
|---|---|---|---|---|
| Center | Innovation-driven economies (GDP per capita > 17000) | 35 | 94,96 | 61,69 |
| Half-periphery | Economies, that are transformation from efficiency-driven to innovation-driven (9000≤ GDP per capita < 17000) | 17 | 2,97 | 28,18 |
| | Efficiency-driven economies (3000 ≤ GDP per capita < 8999) | 30 | 1,72 | 6,31 |
| Periphery | Economies, that are transformation from factor-driven to efficiency-driven (2000≤ GDP per capita < 3000) | 19 | 0,34 | 3,54 |
| | including Ukraine (2014) | | 0,04 | 0,31 |
| | Factor-driven economies (GPD per capita (current USD) < 2000 or high dependency on mineral resources*) | 37 | 0,01 | 0,28 |

* This is measured by the share of exports of mineral goods in total exports (goods and services), and assumes that countries with more than 70% of their exports made up of mineral products (measured using a five-year average) are to a large extent factor driven.

Note: developed by authors with using [6–7].

The decomposition conducted on the basis of «functional specialization in the reproduction of innovation», allow you to select a part of the most advance configuration of NIS (generation of integrated networks G5 [9]) the following segments.

1. The *segment of knowledge generation* formed by scientific institutions and organizations, regardless of patterns of ownership carry out scientific research and development, create new scientific and technical and social knowledge and technologies of their practical use, offer new meanings, initiatives and forms of cooperation in the field of research and development.

2. The *manufacturing segment*, consisting of organizations and enterprises based on their own research or through technology transfer produce high-innovative products, providing innovative services and (or) is introducers/users of technological, organizational or marketing innovation.

3. The *innovation infrastructure segment*, elements of which are companies, organizations, institutions, enterprises and their associations on commercial, nonprofit or mixed (partial self-financing) basis, provide a variety of services to ensure innovation. In addition to resource support this segment is designed to:

- overcome morphological problems of functioning and development due to spatial remoteness and heterogeneity of elements of NIS;
- reducing lag transformation of scientific intellectual product into the market commercial commodity forms;
- improving the efficiency of innovation activities of economic players due:
  - ✓ reducing transaction costs and waste of time at innovative communications;

✓ optimize network bandwidth corresponding commodity resource flows and their accumulation and sewerage;

✓ improvement of flexibility of NIS (redundancy mechanisms, insurance, partial duplication of the mediation, including the transfer innovative ideas and technologies);

✓ reduction of maturities and payback of innovation capital;

✓ acceleration of information flows in the feedback loop and reduce the lag system to respond to changes in the environment;

• coherence of efforts of players through the solution or mitigation contradictions that trigger state bifurcation in the innovation process.

4. *Households segment* that combines the role of owners economic, and intellectual resources, beneficiaries and users innovative goods and services, media of needs and expectations regarding their future qualities.

5. Public segment – the spokesman and defender of the public interest and (or) the collective interests of certain social groups the expert in matters of conformity to the political-economic reality of public expectations regarding it. This segment is the auditor of public governance and government-owned, the translator of the public opinion on important institutional innovations, which also contributes to their development and implementation also public organizations realize certain accumulation of social power and the direction of its for forcing of innovation processes. Social networking sites have become the generation and transfer of knowledge, a new universal tool for the development of current and future demand for private and public good innovation [10-12].

6. The segment of state coordination and regulation of innovation as a set of institutions, which:

• determine structural features of construction and principles of interaction of all components of the NIS, provide symbiotic harmonized development and, if it is necessary, compensate or eliminate the existing disparities;

• define priorities of the development of NIS, vectors, principles and ways of its integration into the global and regional innovation space;

• set and ensure compliance with the requirements and regulations in the sphere of innovations;

• coordinate the innovation interests of actors-maximizes for implementation the strategic tasks of the country in an innovative way. The State should: a) promote the benefits of innovation development highlight the negative consequences of an innovative autarky and the appropriateness of innovation cooperation; b) develop technologies of formation a shared vision of problems and prospects of co-production at potential participants of innovative interactions, search for consensus in the co-creation of new innovation ideas, design and launch of chain the co-creation of value's chains [13]; c) distribute advanced forms of scientific cooperation and innovative entrepreneurship, encourage any public safety collective and individual innovation initiatives of economic actors [14];

• in accordance with the view of the future contribute the development and diffusion of high (advanced), critical and strategic technologies, provide an active innovation policy, especially selective support of national priorities of scientific-technical and innovation development;

• regulate international aspects of the NIS in particular are responsible for creating conditions for its convergence with innovation systems of other countries, stimulate international scientific and innovation cooperation, intelligent protectionism in relation to domestic producers of high and medium technology products.

The boundaries and the internal environment of NIS are constantly changing as continuously there are processes of emergence of new knowledge and technology, the implementation of expansionary policies, the creation of new businesses and industries, the formation of new connections, change and differentiation of target markets, etc. Such their dynamism and flexibility distinguished NIS from other macro-form organization of scientific-technical and innovation, and gives it the ability to quickly and effectively adapt to changes in the external environment and domestic socio-economic policy.

The subjects of NIS and the interaction

between them define the configuration limits and macroscopic properties of the system. Clearly, quantitative and qualitative characteristics of the flow of innovation processes cannot be the same in different socio-economic conditions. They form a national model of innovation development in its concrete historical combination with complex of supporting mechanisms and external relations.

- Generalization of numerical results of comparing of NIS [15–18] allows to determine the grounds in which the specificity of national configuration manifest the most clearly (Table 2) developed competitive advantages, above all, self-provision with available specialized resources, uneven of their territorial concentration;
- more or less share the role of government and the private sector in financing R & D and innovation processes;
- innovative business activity, the share of innovation, attributable to the share of small and medium enterprises (SMEs);
- completeness reproduction cycle of innovation, ratio of basic, applied research and R & D, their diversification on fields of knowledge and economic activities;
- technological structure of innovative activity;
- foreign economic structure and its orientation (export expansion or import substitution);
- preferred forms, the nature and depth of integration into the global innovation space the degree of openness and protectionism;
- type and strategy of development;
- dynamics of results and efficiency and etc.

The awareness of the leading role of innovation in maintaining of positive economic dynamics encourages numerical international organizations to start on its base their own work on the creation of methods of evaluation the innovativeness of countries of the world. At the same time they offered an agreed view on innovativeness as on the qualimetric macroscopic characteristic of the national economy, that generically displays its existing innovative potential and current results, and efficiency of this potential [4-5].

The typical algorithm of ranking the national economies by the level of innovativeness includes the following steps.

1. Substantiation and determining the structure of the index (the number of aggregated subindexes, degree of detail in the initial performance, integration options ({initial parameters} → {subindexes of lower level} → ... → {subindexes of the highest level} → integral index) scales of meanings for all components and their weight coefficients (if it is necessary).

2. Selection of input data, clarification of ways and sources of getting primary data, methods of verification.

3. Determination of the list of countries that would be subject of inspection and, if necessary, the criteria for their differentiation and grouping that will identify something special in their innovation development.

4. Formation the array of input data. Clarification the order of action in the absence some of them.

5. Division initial indicators on the factors of positive and negative influence. Normalization the first of them is carried out under the method of min-max, the second - max-min, which is used under inconsistencies of the scale of measurement initial data and the scale of measurement of meanings were adopted in the methodology.

6. Calculation of the integral index and subindexes for each country, and of the whole sample of surveyed countries. Usually the meaning of an integrated index and subindexes of the highest order are compared or with the median or with weighted average and are submitted over the previous period.

7. Streamlining of countries concerning decreasing / increasing of their integrated index, assignment of the relevant ranks.

8. Presentation of received results.

It should be noted that in order to avoid the accusations of political bias, the most respected developers of global indices (UNDP, WIPO, World Bank, World Economic Forum, IMF, European Commission and others) a priori reject the critical value judgments and obsessions recommendations. Profiles of individual countries contain "food for thought" - the specific data in absolute or relative terms with symbolic fixation of their "strong" and "weak" sides. The means of an integral national index and subindexes of higher order are compared or with the medians, averages or weighted averag-

es for the entire sample of surveyed countries, or with the averages, calculated for a particular group, and presented with compare to previous period. Only bright "failures" and "breakthroughs" of the year deserve special attention and detailed analyzes of the causes of failures or success.

Table 2

Models of NIS and their classification

| Classification feature | | Conditional model name | Characteristic |
|---|---|---|---|
| A catalyst of development | | Market | Innovation activity is subdued of competition and market logic. Cooperation in an innovation sphere takes place mainly at the initiative of privet subject of a national economy. Self-organization processes are dominated. |
| | | State support (coordination and regulation) of innovative activity | State protectionism and paternalism national innovation development institutions. Carrying out an active state innovation policy. |
| Latitude of scientific and technical interests | | Diversified | R&D activity covers all key areas of scientific and technological progress |
| | | Specialized | Areas of research are limited and agreed with the national priorities of competitiveness |
| Territorial scope of coverage | | Local innovation environment | The concentration of a particular area of scientific, educational, industrial and financial potential (techno-policies, incubators, techno- parks) |
| | | Polycentrism | The interaction of relatively local regional innovation-active zones on a national scale |
| | | Full coverage of an economic area | Manifestations of innovative activity are relatively evenly distributed by regions of the country |
| Completeness of the reproduction cycle of scientific and technical knowledge and innovation | With incomplete cycle | Commodity cloning | Enterprises are mastering the production of high-tech products in the countries of post-industrialism, being there on the stage of maturity of the product life cycle |
| | | Licensing and copying | Use of foreign scientific and technological capacity by legal using of intellectual property rights |
| | | Technological «second hand» | Issue of mass medium-tech and low-tech products with using of exported morally outdated technological lines and equipment, which were decommissioned in the countries – importers. |
| | Self - development (Full cycle of R&D and innovation process) | | Formation and of using national scientific and technological capacity mainly based on the their own efforts and resources |
| Innovation strategy | | Chasing the leader | Innovations, that are aimed at improving of externally borrowed innovative technology, dominate (passive modernization strategy) |
| | | Technological leadership and development to advance | Focusing on own design of radically new technologies (active, breakthrough strategy) |

Note: developed by authors with using [15–18].

By the same principle annually Summary Innovation Index is calculated by the European Commission within the statistical and analytical platform named European Innovation

Scoreboard. For us it is interesting in that the sample of surveyed countries over the past five years contains Ukraine. Based on the relevant data (fig. 3), it can be received a real idea of positioning of NIS of Ukraine in European innovation space and its status (fig. 4).

Typologization of state NIS segment based on the differences in patterns of behaviour, breadth of competencies (the area of responsibility), on the technologies of purpose implementation and the exclusivity of approaches to coordination and regulation of innovative micro-processes [19]. According to the latest feature a reflexive and creative approaches are distinguished. The first implies the adaptation of public policy to the realities of innovation dynamics, their adjustment with taking into account the specific of already formed structure of NIS (for example UK). The second implies a significant state influence on the drafting the project of development of NIS, definition of configuration and institutional design, direct active participation in system's creation, reconfiguration (for example France).

The practice demonstrates the possibility of building the NIS in two variants: either

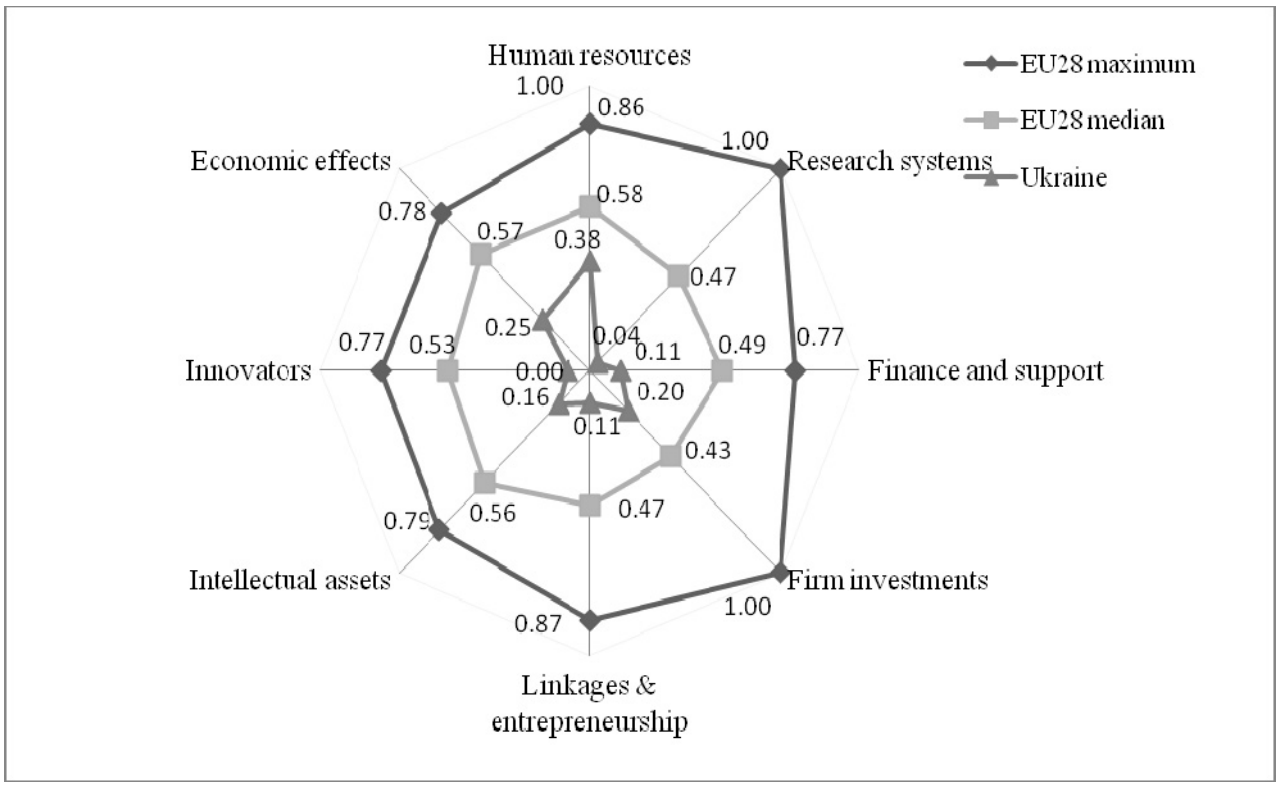


Figure 3. Key indicators of Summary Innovation Index-2016 for Ukraine comparison to the EU28-median and EU28-maximum [developed by authors with using [5]]

authentic, which are based on national traditions (countries - «old» and «new» technological leaders (Asia-10)), or by copying the "paradigmatic", selected to be followed models of NIS (developing countries of Latin America).

Realization of the construction project includes of three alternatives:

- the particular in which the objects of state support are specific elements of NIS (for example USA);
- the integrative that is focused on the building up the communications system of endogenous character mostly (for example Japan) or mixed endogenous-exogenous character (for example Singapore, countries of Scandinavia);
- the complex when the state support extends both on the elements and on the internal relationships.

NIS's regulation can be either built into a macro-system of socio-economic policy and proceed from the premise of subordination of the national innovation interests to the state-nation's strategic economic interests (for example – Germany, Switzerland), or can act as a relatively independent regulation direction (for example – Spain, Italy).

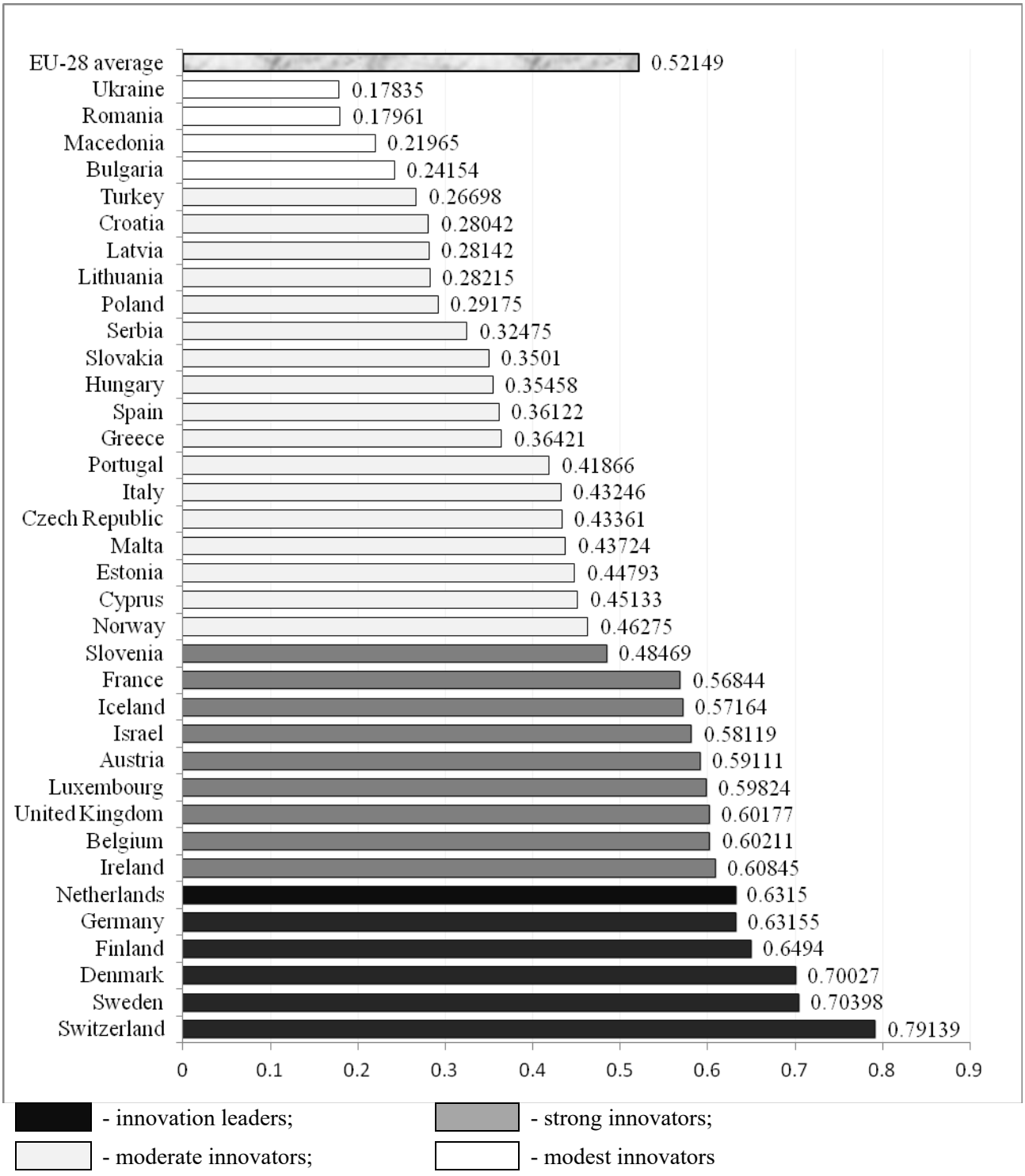


Figure 4. Ranking of EU Members and non-EU countries – partners or potential EU members by Summary Innovation Index-2016 [5]

Ideally, a model of NIS, which is correlated with the overall strategy of socio-economic development under its driving forces, its vectors of integration and the results, should be formed as a result of process of innovative system's creation. It should be expected the formation of innovative interactive space that will generate and distribute innovation impulses for economic growth in the national economy off one's own bat, under the conditions of coherence between all participants of the innovation process, harmonization (agreeing) of their innovative interests, by the effective coordination and regulation.

**Conclusion.** Currently NIS is the highest institutional macro-form of coordination and

regulation of the innovation processes. The necessity of ensure the management solutions by relevant information about successful international experience of innovative system's creation determines the relevance of comparing the national innovation systems and their typology. The latest appropriate to conduct relying on the taxon of detected complementary classification features, in which the specificity of national configuration of NIS and the uniqueness of interaction of its elements in particular in the agreeing the economic subjects innovation interests manifest the most clearly.

Prospects for further research are: a) the concretization of quantitative indicators-identifiers of individual types of NIS; b) determining competitive advantages and constructional features of NIS of Ukraine, its typology by taxon of criteria that marked in article; c) the search of international experience on the functioning and development of similar NIS's, its adaptation to national conditions and its using under the implementation of the national strategy of innovation development.

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## НАЦІОНАЛЬНІ ІННОВАЦІЙНІ СИСТЕМИ: КЛАСИФІКАЦІЯ, РЕЙТИНГУВАННЯ ТА ПОЗИЦІОНУВАННЯ В ГЛОБАЛЬНОМУ ІННОВАЦІЙНОМУ ПРОСТОРІ

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У статті обґрунтовується практична актуальність компаративістичних досліджень національних інноваційних систем (НІС). Конкретизуються класифікаційні ознаки та прояви національної специфіки моделей НІС. Наводиться та реалізується методика позиціювання

НІС України у глобальному та регіональному (європейському) інноваційному просторі.

***Ключові слова:*** національна інноваційна система, національна модель, класифікаційні ознаки, типологізація, технологічна піраміда, інноваційний центр, інноваційна периферія.

## НАЦИОНАЛЬНЫЕ ИННОВАЦИОННЫЕ СИСТЕМЫ: КЛАССИФИКАЦИЯ, РЕЙТИНГИРОВАНИЕ И ПОЗИЦИОНИРОВАНИЕ В ГЛОБАЛЬНОМ ИННОВАЦИОННОМ ПРОСТРАНСТВЕ

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В статье обосновывается практическая актуальность компаративистических исследований национальных инновационных систем (НИС). Конкретизируются классификационные признаки и формы проявления национальной специфики моделей НИС. Раскрывается и реализуется методика позиционирования НИС Украины в глобальном и региональном (европейском) инновационном пространстве.

***Ключевые слова***: национальная инновационная система, национальная модель, классификационные признаки, типологизация, технологическая пирамида, инновационный центр, инновационная периферия.

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