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# INTEGRATION PRINCIPLES FOR THE IMPLEMENTATION OF OPTIMIZATION PROCESSES IN THE STRUCTURE OF THE NANOSECTOR OF THE NATIONAL ECONOMY OF UKRAINE

## Abstract

The article examines the development of the third area of the nanoeconomy – the economy of nanotechnology – and emphasizes the importance of innovation for the country's economic growth. The authors emphasize the need to create a legislative framework to support nanobusiness, the development of technology parks, and tax incentives. The authors also emphasize the importance of Ukraine's transition to modern scientific and technical systems for integrating



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nanotechnology into the economy. The processes of regrouping the country's regions and creating new clusters are identified, facilitating the interaction of innovative segments of the economies of different regions.

## Key Words:

nanoeconomy, nanosector, national economy, integration processes, optimization processes, structure of the nanosector.

**JEL:** H00; H80; O41.

6 tables, 15 references.

## Problem Statement

The third area of the nano economy, the economy of nanotechnology, is developing rapidly in today's realities. In our opinion, an indicator such as the innovation adoption rate can be helpful in any country. Therefore, it is essential to have a legislative framework to support nano businesses. Scientists point out that small businesses of various ownership and organizational structures create experimental samples of highly priced nano products.

Such enterprises should appear in Ukraine, but for their successful operation, it is necessary to develop appropriate legislative mechanisms and tax incentives. For instance, countries like the United States and Japan have successfully implemented tax incentives and legislative frameworks to support nanotechnology businesses. It is also important to accelerate the creation of technology parks to stimulate research and development in the field of nanotechnology. Nanotechnology innovations are developing within the sixth and seventh scientific and technological stages, while the Ukrainian economy corresponds to the third and fourth stages.

It is urgent for Ukraine to go through all stages of economic innovation and make a radical transition to the newest areas of economic and innovative development for the successful development of nanotechnology. The study shows that regional groups formed in Soviet times are now being reformatted. New clusters are emerging that are characteristic of fewer regions of Ukraine. This means that regional clusters are beginning to unite regions from different parts of the country, for example, Donetsk region is combined with Volyn and Khmelnytsky, and Sumy region with Zaporizhzhia. This creates preconditions for the integration of innovative segments of the economies of different regions of Ukraine.

## Literature Review

Accordingly, in today's environment, it is necessary to have a legislative framework to support nanobusiness. Various scientists have shown that small businesses of various forms of ownership and organizational structure produce experimental samples of nanoproducts and offer a correspondingly high price for them (Ostapenko et al., 2024).

Such enterprises should start operating in Ukraine, but for optimal operation, it is necessary to create legislative conditions and tax incentives for business. It would be desirable to accelerate the creation of technology parks for research and nanotechnology development. Nano-innovations are being developed within the framework of the sixth and seventh scientific and technological orders, but Ukraine's economy corresponds to the existence of the third and fourth orders. To develop nanotechnologies, it is necessary to go through all the stages of the innovation economy and radically move into the newest areas of the economic and innovation environment.

For example, nanophysics and nanotechnology occupy one part of the report of the National Academy of Sciences of Ukraine. These technologies were developed at the Institute of Physics of the National Academy of Sciences of Ukraine, creating large-area near-infrared radiation sources. They also achieved a significant (6-fold) enhancement of the photoluminescence of carbon nanotubes and determined its mechanism. Scientists from Aston University in the United Kingdom and Ukrainian researchers conducted this analysis. Corresponding members and academicians of the National Academy of Sciences of Ukraine led these research areas (National Academy of Sciences of Ukraine, 2020).

The National Academy of Sciences of Ukraine institutions have been implementing various nano developments: Kurdyumov Institute of Metallophysics, Bogolyubov Institute of Theoretical Physics, Institute of Magnetism, Verkin Institute of Physics and Technology of Low Temperatures (National Academy of Sciences of Ukraine, 2020).

The V.E. Lashkarev Institute of Semiconductor Physics conducts fruitful research in nanophysics. They have created surface microreliefs with controlled parameters depending on the doping of n-GaAs and InP substrates. Deposition of gold nanoparticles (nanowires) on top of the microrelief of substrates. This institute, together with the State Enterprise Research Institute «Orion», conducted research on the technology of manufacturing Hahn pulse diodes in the form of a mesostructure. These circumstances are an example of the combination of scientific efforts of the institutes of the National Academy of Sciences of Ukraine and production enterprises (National Academy of Sciences of Ukraine, 2020).

In this 2020 Institute of Semiconductor Physics, it was found that the growth mechanism of 20-period GaN/AlN-on-GaN(0001)-sapphire template films changes with increasing thickness ratio of the pit/barrier layers from columnar to planar (two-dimensional) growth. It is shown that the relaxation of the films increases with the number of periods. The peculiarities of the influence of the anisotropy of the piezoelectric polarization properties of crystalline trinitride structures on their local electrophysical characteristics are clarified (National Academy of Sciences of Ukraine, 2020).

Nanotechnology research is carried out by various structures of the National Academy of Sciences of Ukraine, from the Bogolyubov Institute of Theoretical Physics to the Ukrainian Research Institute of Forestry and Agricultural Reclamation of the Vysotsky State Forestry Agency of Ukraine and the National Academy of Sciences of Ukraine. The Research Institute of the National Academy of Sciences of Ukraine researches nanotechnology. The results are published in various scientific periodicals. These include: «Physics and Chemistry of Solids»; «Metallophysics and Newest Technologies,»; «Ukrainian Physical Journal»; «Ukrainian Chemical Journal»; «Chemistry, Physics, and Surface Technology»; «Journal of Nano- and Electronic Physics».

Various institutes and universities in Ukraine also deal with nanotechnology problems, including the Kyiv Polytechnic Institute (publishes the «Bulletin. Series: Chemical Engineering: Ecology and Resource Conservation»). Lviv Polytechnic University also researches this issue (it publishes a textbook, «Theory and Practice of Construction,» with a definition of nanotechnology in construction). Zhytomyr National Agroecological University publishes research on nanopreparations in crop production. «The Bulletin of the Engineering Academy of Ukraine publishes the results of a study on nanomaterials and nanotechnology in engineering (National Academy of Sciences of Ukraine, 2020).

**The purpose of this study is** to identify and further outline the integration principles for implementing various optimization processes in the structure of the nano sector of the Ukrainian national economy.

## Methodology

We propose a comprehensive cluster analysis to determine the participation of Ukrainian regions in innovation activities and, potentially, in the global innovation environment. For this purpose, we will take the initial data on the regions of Ukraine and Kyiv, which are presented in the environment of the statistical package «Statistica 12».

The main indicators used for the analysis are as follows:

1Var1. Organizations that perform scientific work;

2Var2. Number of researchers, doctors of sciences;

3Var3. Number of researchers, PhDs;

4Var4. Number of researchers who have traveled outside Ukraine;

5Var5. Received titles of protection for inventions;

6Var6. Number of industrial enterprises that implemented innovations;

7Var7. Volumes of innovative products sold outside Ukraine;

8Var8. Acquisition of new technologies outside Ukraine;

9Var9. Transfer of new technologies outside Ukraine;

10Var10. Innovative cooperation with foreign partners (European countries).

The division of the set of research objects into homogeneous groups is the cluster analysis procedure used to reduce the data. Cluster analysis works by grouping similar data points together, thereby reducing the complexity of the data set. This process, which can also be applied when it comes to creating groups based on quantitative characteristics, is a key part of our research methodology (Tymchyshak, Pavlova & Pavlov, 2023).

Cluster analysis differs from other statistical methods in that there is no sample. The decisive advantage of cluster analysis is the ability to categorize objects not by a single parameter but by several parameters. At the same time, the use of cluster analysis complicates the application of conventional econometric methods.

The solution to the cluster analysis problem is a distribution that satisfies the optimality criterion. There are many cluster analysis algorithms, with hierarchical (tree-like) processes being the most common, especially regarding software and hardware implementation (Cifuentes-Faura & Francesco, 2022). These algorithms operate on the principle of systematically grouping elements, starting with the closest and then the most distant ones. However, their algorithmic implementation is often cumbersome, posing a significant challenge (OECD, 2024).

Each step of the algorithm, a complex process, necessitates the meticulous calculation of a matrix of distances, time, and machine resources, underscoring the depth of our research.

The diversity of solutions that can be derived from differentiating the innovation clusters into various numbers in Ukraine underscores the breadth of our research.

The meticulous process in the «Statistica 12» environment, where we select the Cluster Analysis command in the Statistics / Multivariate Research Methods menu and the tree clustering method among the available clustering methods, demonstrates the thoroughness of our research.

The results of the clustering procedure were included in the following scheme:

- clustering rule;
- horizontal tree diagram;
- vertical tree diagram;
- graph of the clustering order;
- distance matrix.

This data allows us to track the process of cluster analysis. In the first stage, we assume that each region is a separate cluster, i.e., 25 clusters. According to the distance matrix, which is a crucial tool in determining the similarity between clusters, the smallest distance between clusters is determined. Thus, between clusters C13 and C20, the Euclidean distance is 2985, between C16 and C18 - 236, C5 and C10 - 4804, C8 and C22 - 6825, which proves that it is possible to make the first combination into clusters: C1, (C13, C20), (C16, C18), C23, C21, C24, (C5, C10), (C8, C22), C14, C9, C25, C12, C2, C6, C11, C15, C3, C7, C17, C19, C4. Vertical or horizontal tree diagrams confirm This combination by the rule of association. This means that we get 21 clusters. Since the study aims to obtain 5 clusters, the clustering procedure should be continued according to the same scheme. At a particular step, we get the following division into 5 clusters.

Ci - is determined by the number of the corresponding i-th region in the initial data table. This ‘Ci’ serves as a unique identifier for each region, allowing us to track and analyze the data for each region individually, which is crucial in the clustering process.

Thus, the cluster analysis has determined that most regions of Ukraine are similar in developing innovation activities, and their nanoeconomy needs to be improved. This similarity suggests that a uniform approach to innovation development may be effective across these regions. All the initial data for the cluster analysis show that the intensification of innovation activity should begin with family, preschool, and university education. These regions should develop the education economy for the next opportunity to develop creative individuals to develop and implement high and nanotechnology. In the Kharkiv and Dnipropetrovs'k regions, creating conditions for the use of innovations by enterprises that produce goods or services is necessary. At the same time, it is necessary to support the scientific potential by developing the economy of education and training to transition to the human economy and the economy of nanotechnology (Yakymchuk et al., 2021).

For successful application of Kmeans_arma, it's crucial that the number of columns (vector variables) in the data exceeds the number of clusters. This condition is not just a technicality, but a fundamental requirement. Failing to meet this criterion will result in an error. The algorithm is initiated once; usually, ten iterations are sufficient for convergence. The initial centroids are distributed using one of the algorithms – *keep_existing, static_subset, random_subset, static_spread, or random_spread.*

## Research Results

One state of economic development turns into another, which characterizes the cyclical nature of the process.

Scientific and technical systems determine it as a period of transformation of scientific and technical research. The fifth mode is currently active. It is informational and characterized by the development of industries such as electronics, telecommunications, software, robotics, and high biotechnology. Information and biotechnology are inherent in the fifth and early sixth technological orders, while industrial technologies are the basis of the previous four orders.

The combination of evolutionary development and revolutions of technological progress is a sign of the emergence of a new technological order. It is manifested by progressively cyclical growth due to capital accumulation and the replacement of technical equipment. The modes emerge at different stages of Kondratieff's long waves.

The newest sixth mode is being formed in Ukraine, but the entire industry is based on the previous technological modes (Ostapenko et al., 2024).

Saturation is a sign of industrial development in Ukraine. Statistical publications provide data on the development of Ukrainian industry. The traditions of industrial production in the country are formed in metallurgy, which is an industry of international specialization in Ukraine.

Industrial development in Ukraine is quite intense. The main industry is metallurgy, a long-standing traditional industry in Ukraine's specialization in the global environment.

*Table 1*

**Production of certain types of steel products in Ukraine (million tons)**

| Year | Pig iron and mirror cast iron in ingots, ingots and other primary forms | Steel without semi-finished products produced by continuous casting | Semi-finished products produced by continuous casting | Pipes and tubes, hollow profiles, made of steel |
|---|---|---|---|---|
| 1990 | 41,9 | 48,5 | 4,1 | 6,5 |
| 2000 | 25,3 | 25,8 | 6,0 | 1,7 |
| 2011 | 27,3 | 17,5 | 15,8 | 2,0 |
| 2012 | 28,9 | 17,6 | 17,8 | 2,4 |
| 2013 | 28,5 | 16,6 | 16,9 | 2,2 |
| 2014 | 29,1 | 15,1 | 18,1 | 1,8 |
| 2015 | 24,8 | 12,7 | 14,7 | 1,6 |
| 2016 | 21,9 | 11,2 | 11,9 | 1,0 |
| 2017 | 23,9 | 9,2 | 8,0 | No data available |
| 2018 | 19,8 | 9,1 | 5,0 | No data available |
| 2019 | No data available | No data available | 2,5 | No data available |
| 2020 | 20,1 | No data available | 9,4 | 1,5 |
| 2021 | 20,2 | No data available | 10,1 | No data available |

Source: developed by authors. Based on State Statistics Service of Ukraine (2024).

Table 1 shows the production volumes of certain types of metallurgical products.

The ongoing hostilities in Ukraine have had a profound impact on the steel industry in the east, with some plants being completely destroyed. Since the significant events of 1991, iron and steel production has nearly halved, while the production of semi-finished products has quadrupled. Despite these challenges, Ukrainian products continue to be exported to foreign markets, with their demand steadily increasing (Usatenko, 2013).

It should be noted that Ukraine uses blast furnaces and open-hearth metal production, which correspond to the second and third technological systems. Such production is quite expensive and resource intensive. Urgent action is needed to re-equip plants to use the technologies of the later stages, to ensure the competitiveness of the industry in the global market.

Ukraine's steel industry is a diverse and robust sector, producing a wide range of commodity products. These include pig iron, ferroalloys, steel without semi-finished products, semi-finished products, rolled ferrous products, pipes and tubes, open-ended profiles, profiled sheets, steel wire, building structures, plates and bars, central heating radiators, central heating boilers, tanks and cisterns, steam boilers, and ferrous fasteners. All of these goods are manufactured in Ukraine and are in demand in international markets (Wenger, 2022).

The near-crisis environmental situation in the steel industry raises the urgent need to transform the technological equipment of plants by the sixth technological system. 794.4 thousand tons of substances are released into the environment every year. Pollutants account for 27.8% of total emissions, including 40544.5 thousand tons of carbon dioxide (State Statistics Service of Ukraine, 2024).

Increased consumer demand for product quality and price dictates the conditions for the transition to a new technological structure. Accordingly, the main consumer of steel products is the machine building industry. The special technological component of the machine-building industry in Ukraine allows the use of metal produced using outdated technologies. Ukraine's machine building industry is mechanical, electrical and automatic. All of these processes are material-intensive if high-quality metal is required, but there is enough of it and it is consumed in excess (Dorofyeyev, Lozinska, Ponochovnyi & Vlasenko, 2020).

Clusters are industry bundles consisting of related and supporting industries.

Moreover, another one is the agro-industrial complex-engineering nexus. The endogenous approach to economic growth implies internal impulses for economic progress. The impulses for economic development in Ukraine are domestic machinery producers for harvesting and processing crops. Agricultural machinery in Ukraine includes tractors for agriculture and forestry, plows, cultivators and cultivators, disk harrows, seeders, mowers, grain harvesters, sprayers and sprinklers, and animal feed preparation machines. Modernizing this equipment with the use of information technology can significantly improve efficiency, reduce labor costs, and increase productivity. Machinery for food production should also be replaced with the use of, say, Italian technological solutions.

Automobile production is one of the world's leading industries. However, Zaporizhzhia Automobile Factory almost never produces new cars. This underscores the urgent need for a comprehensive strategy at the state level to revitalize and develop this industry, a need that cannot be overstated.

With the advent of nanotechnology in the chemical sciences, the potential for its implementation in chemical products is vast. Nanotechnology can enhance the properties of chemical products, improve their performance, and reduce production costs. The list of chemical products in Ukraine is as follows: synthetic dyes, organic dyes, metalloids, sulfuric acid, sodium hydroxide, cyclic hydrocarbons, ethyl alcohol, anhydrous ammonia, urea, ammonium nitrate, ethylene polymers, urea resins, paints and varnishes based on polyester, soaps, detergents, etc. The adoption of nanotechnology solutions could revolutionize these industries, which are currently using outdated technologies from the mid-twentieth century.

The leader of the chemical industry is the pharmaceutical industry, which is not just developing, but actively thriving in the world. Statistics on the production of pharmaceuticals are presented in Table 2 (pharmaceuticals manufactured in Ukraine) (Asheim, Boschma & Cooke, 2011).

The antibiotics produced contain penicillin, but the global pharmaceutical industry uses more modern types of these drugs and increases profits by supplying these products abroad.

The conditions for the development of the fifth and sixth technological orders include those pharmaceutical companies that produce contraceptives, antihistamines, and anti-oncology drugs. Ukrainian pharmacists should cooperate more actively with national academic institutions to use nanotechnology, which can facilitate a leap to the next mode (Coenen, Moodysson & Asheim, 2004).

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*Table 2*

**Production of main pharmaceutical products in 2021 (kg)**

| Code | Product name | Girth, kg |
|---|---|---|
| 1184 | Medicinal products containing penicillin or their derivatives, having the structure of penicillic acid, or containing streptomycin or their derivatives, in dosage form or packaged for retail sale | 46901 |
| 1185 | Drugs containing antibiotics, packaged for retail sale | 294595,5 |
| 1186 | Drug preparations containing insulin and not containing other antibiotics, for therapeutic or prophylactic use, in dosage form or packaged for retail sale | к/с |
| 1187 | Medicinal products containing corticosteroid hormones, their derivatives and structural analogues, and not containing antibiotics, for therapeutic or prophylactic use, in dosage form or packaged for retail sale | 28186,7 |

| Code | Product name | Girth, kg |
|---|---|---|
| 1188 | Medicinal preparations (containing iodine or its compounds, chitin, etc.), n.o.s., for therapeutic or prophylactic use, not packaged for retail sale | 166252 |
| 1189 | Drugs containing alkaloids or their derivatives, packaged for retail sale | 750369 |
| 1190 | Other medicinal preparations containing vitamins or provitamins, their derivatives and mixtures, for therapeutic or prophylactic use, in dosage form or packaged for retail sale | 60906,9 |
| 1191 | Other drugs containing mixed or unmixed products, n.o.s., packaged for retail sale | 11298698,1 |

Source: developed by authors. Based on State Statistics Service of Ukraine (2024).

The new system is a benchmark for improving the country's innovation system. The cooperative model of the innovation economy implies the existence of a triangle of enterprises – universities – state government agencies. At the nanoscale, the pivotal roles of individual researchers in universities, managers and scientists in state government agencies, and engineers and entrepreneurs in enterprises are integral to the system's operation. To understand the conditions for the transition to new technological systems, it is necessary to characterize these elements of the cooperative system. In the 2021/2022 academic year, there were 338 higher education institutions of lower accreditation levels and 281 higher education institutions of higher accreditation levels (State Statistics Service of Ukraine, 2024).

It should be noted that since 1995/1996, the number of higher education institutions of the I-II accreditation level has halved from 782 institutions. The number of students in higher education institutions of the I-II accreditation level has decreased from 617.7 thousand (1995/1996) to 173.6 thousand (2021/2022). The number of students in higher education institutions of the III-IV accreditation level increased from 922.8 thousand to 1266.1 thousand, respectively. In the first year of study, 446573 students were admitted to universities (2022), of whom 142434 were enrolled at the expense of the state budget. Twenty thousand seventy-four people studied at the expense of local budgets. In the same year, 421131 students graduated (State Statistics Service of Ukraine, 2024).

*Table 3*

**Training of specialists by educational degrees in the 2021-2022 academic year in Ukraine**

| | Applications for the initial cycle of training accepted |
|---|---|
| Total | 1045251 |
| By educational and qualification levels: | |
| Master | 256115 |
| Bachelor's degree | 686508 |
| Young Bachelor | 59759 |

Source: developed by authors. Based on State Statistics Service of Ukraine (2024).

Table 3 shows the number of students enrolled by different educational qualification levels. The table shows that most students are enrolled in Bachelor's and Junior Bachelor's degrees. Master's degree programs have a small number of students. Competencies corresponding to the sixth and seventh technological orders are necessary for free competition in the labor market. Therefore, it is necessary to have a PhD or doctoral degree to have the status of a developer and implementer of the latest technological solutions.

It should be noted that the number of postgraduate and doctoral students in Ukraine is increasing. In the mid-1990s, 374 institutions had postgraduate programs, and 158 had doctoral programs. Today, the numbers are 417 and 253, respectively. There were 7493 PhDs and 563 doctors (State Statistics Service of Ukraine, 2024).

Statistics show that scientific research is a promising and prestigious activity. Research conducted at various scientific institutions is of a diverse nature (State Statistics Service of Ukraine, 2024).

Table 4 shows information on different areas of science and the number of researchers with a PhD degree. According to the table, most researchers are attracted to engineering and natural sciences. In the social sciences, most researchers are women (over 65%). Thus, there are more men in the technical and natural sciences and more women in the humanities and social sciences (OECD, 2024).

*Table 4*

**Number of researchers by gender in the fields of science, as of January 01, 2023**

| | Number of researchers | | |
|---|---|---|---|
| | of all | including women | % to the number of researchers |
| *Total* | 78860 | 26533 | 44,6 |
| Natural sciences | 16593 | 7337 | 44,2 |
| Technical sciences | 25715 | 8650 | 33,6 |
| Medical | 3759 | 2455 | 65,3 |
| Agricultural | 4777 | 2624 | 54,9 |
| Public | 5945 | 3903 | 65,6 |
| Humanitarian | 2603 | 1562 | 60,0 |

Source: developed by authors. Based on State Statistics Service of Ukraine (2024).

The number of PhDs in science is higher–17949 people–and doctors–7060 people. The presence of scientists determines the research potential. Nano-research determines the quality of science in general and its areas in particular. The following qualitative parameters of nano research, as presented in the esteemed report of the National Academy of Sciences of Ukraine, are crucial for our understanding of this field (National Academy of Sciences of Ukraine, 2020).

The results of the calculations based on the proposed methodological approach are presented in Tables 5 and 6 (Zamlynskyi et al., 2023).

*Table 5*

**Results of the cluster analysis**

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Vinnytska | 0 | 0 | 0 | 1 | 0 |
| Volyn | 1 | 0 | 0 | 0 | 0 |
| Dnipropetrovska | 0 | 0 | 1 | 0 | 0 |
| Donetska | 1 | 0 | 0 | 0 | 0 |
| Zhytomyrska | 1 | 0 | 0 | 0 | 0 |
| Zakarpatska | 0 | 0 | 0 | 1 | 0 |
| Zaporizhska | 0 | 1 | 0 | 0 | 0 |
| Ivano-Frankivska | 0 | 0 | 0 | 1 | 0 |
| Kyivska | 0 | 1 | 0 | 0 | 0 |

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Kirovogradska | 1 | 0 | 0 | 0 | 0 |
| Luhanska | 0 | 0 | 0 | 0 | 1 |
| Lvivska | 0 | 0 | 1 | 0 | 0 |
| Mykolaivska | 0 | 1 | 0 | 0 | 0 |
| Odeska | 0 | 1 | 0 | 0 | 0 |
| Poltavska | 0 | 0 | 0 | 1 | 0 |
| Rivnenska | 1 | 0 | 0 | 0 | 0 |
| Sumyska | 0 | 1 | 0 | 0 | 0 |
| Ternopilska | 1 | 0 | 0 | 0 | 0 |
| Kharkivska | 0 | 0 | 1 | 0 | 0 |
| Khersonska | 0 | 0 | 0 | 1 | 0 |
| Khmelnytska | 1 | 0 | 0 | 0 | 0 |
| Cherkaska | 0 | 0 | 0 | 1 | 0 |
| Chernivetska | 0 | 0 | 0 | 1 | 0 |
| Chernihivska | 0 | 0 | 0 | 0 | 1 |

**Source**: developed by authors.

Thus, the most effective innovation cluster includes Dnipro, Lviv, and Kharkiv regions. Donetsk and Luhansk oblasts in this method are the constituents of different groups – the 1st and 5th clusters.

*Table 6*

**Classification of Ukrainian regions into innovation clusters**

| Cluster 1 | Cluster 2 | Cluster 3 | Cluster 4 | Cluster 5 |
|---|---|---|---|---|
| Volyn | Zaporizhska | Dnipropetrovska | Vinnytska | Luhanska |
| Donetska | Kyivska | Lvivska | Zakarpatska | Chernivetska |
| Zhytomyrska | Mykolaivska | Kharkivska | Ivano-Frankivska | |
| Kirovogradska | Odeska | | Poltavska | |
| Rivnenska | Sumyska | | Khersonska | |
| Ternopilska | | | Cherkaska | |
| Khmelnytska | | | Chernivetska | |

Source: developed by authors.

## Practical Implementation and Limitations

This study shows that the groups of regions formed in Soviet times are now being regrouped. Clusters characteristic of fewer regions of our country are beginning to form. This means that regions from different geographical areas of Ukraine are joining regional clusters. For example, the Donetsk region is combined with the Volyn and Khmelnytsky regions, and the Sumy region is combined with the Zaporizhzhia region. This creates the basis for intertwining the innovative segment of the economies of different regions of Ukraine.

The sixth technological order, still in its formative stages, presents a promising future for all research areas. In Ukraine, a challenge persists: the coexistence of a robust scientific component and the pressing need for its integration with the business sector. However, with concerted efforts, we can bridge this gap. At the state level, we must create an enabling environment for technology payments, such as royalties and lump-sum payments, which should be exempt from income tax.

It’s crucial to note that while science and nano research areas generally align with the requirements of the fifth and early sixth technological orders, the production sector and the innovation process management system lag behind. They have not yet adapted to the demands of the latest technological orders, underscoring the urgent need for transformation.

The nano-economy, with its rich traditions in production and science, must also evolve to meet the demands of the high order. Nanospecialization is shaped by the establishment of traditions in light industry sectors, but these traditions also extend to the newest complex industries. The increasing participation of women in science and production is a positive trend, as it brings diverse perspectives and knowledge into family and household management.

Supporting scientists and manufacturers as part of a single innovation system will help boost the nano economy. It is necessary to support scientists and industrialists at the state level and ensure the procedure of technology transfer from the stage of developing the latest knowledge to the stage of its implementation in production (Ostapenko et al., 2024).

Establishing the technology transfer process should encourage the development of these skills in the country’s educational system. Whether this practice will be applicable in applied production activities depends on the economics of the educational process and upbringing. Thus, a person with the skills to apply the knowledge gained in practical activities can optimally manage the technologies invented in scientific and technical institutions, introducing them into the practical sphere of production (Korogodin, Golikova, Golikova & Beloglazova, 2020).

## Conclusions

In Ukraine, the sixth technological order, still in its formative stages, presents a promising future for all research areas. A key challenge is the coexistence of a robust scientific component and the pressing need for its integration with the business sector. To bridge this gap, we must create an enabling environment for technology payments at the state level. Royalties and lump-sum payments, which should be exempt from income tax, play a crucial role in this integration.

Ukraine's science and nano research areas meet the requirements of the fifth and early sixth technological orders. However, the production sector is relatively backward, with an innovation process management system that is not transformed by the requirements of current technological orders. With its industrial and scientific traditions, the nano-economy must align with the high order of technological advancements. This alignment holds the potential to significantly boost the economy and foster innovation in both traditional and complex industries (Dave & Chaturvedi, 2021).

Supporting scientists and manufacturers as links in a single innovation system will help to activate the nanoeconomy. It is necessary to support scientists and industrialists at the state level and to ensure conditions for the development of technology transfer from the stage of developing the latest fundamental knowledge to the stage of its implementation in production. Technology transfer skills from scientists to consumers of the final product are acquired in educational institutions of different levels. The economics of the educational process and education influence the application practice in applied production activities. This means that a child with the skills to apply the knowledge gained in practical activities can make the best use of the technologies invented in scientific and technical institutions, introducing them into the practical sphere of production.

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